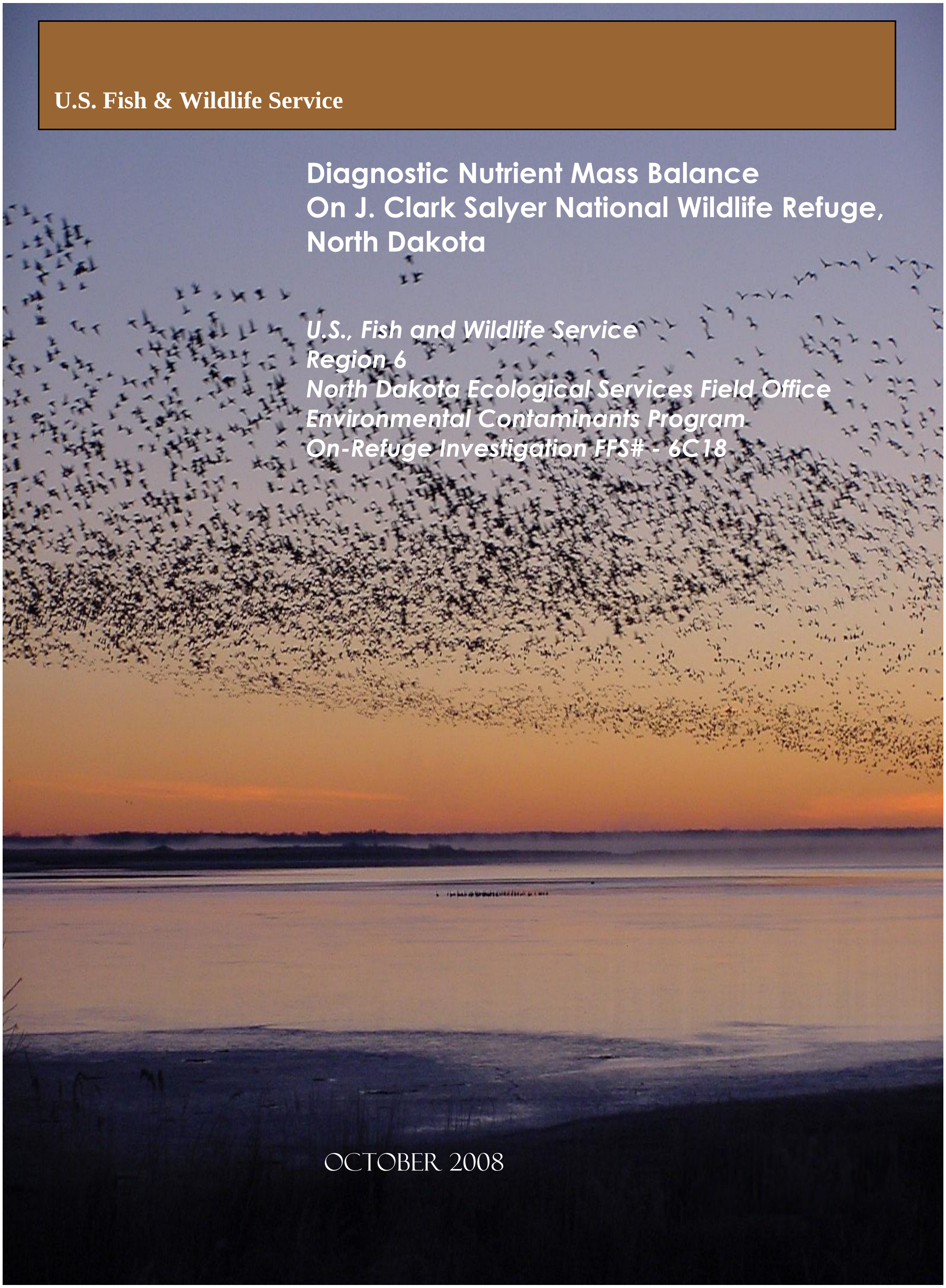


U.S. Fish & Wildlife Service

Diagnostic Nutrient Mass Balance On J. Clark Salyer National Wildlife Refuge, North Dakota

U.S., Fish and Wildlife Service
Region 6
North Dakota Ecological Services Field Office
Environmental Contaminants Program
On-Refuge Investigation FFS# - 6C18

OCTOBER 2008

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The Souris River, an international river originating in Canada's Saskatchewan Province, flows south into the State of North Dakota and then back north into Canada's Manitoba Province. In North Dakota, the river flows through the U.S. Fish and Wildlife Service's 58,700 acre J. Clark Salyer National Wildlife Refuge (Refuge). The Refuge extends approximately 50 miles south from the North Dakota/Manitoba border. The international Souris River Bilateral Water Quality Monitoring Group collects and analyzes water quality samples at specific locations on the Souris River to ensure compliance with trans-boundary water quality objectives and meet the terms of the 1989 International Agreement. Analyses of samples collected in Canada downstream of the Refuge and its impoundments have shown consistent exceedences for several water quality parameters. To address these water quality concerns, the U.S. Fish and Wildlife Service's Environmental Contaminants Program calculated a nutrient budget for the Refuge; identified sources of and quantified nutrient loading; and evaluated methods to reduce loading to the system, subsequently improving Refuge habitat, trophic condition of Refuge pools, and possible downstream water quality. Field work for this investigation was conducted in 1999-2001. 1999 was a flood year for all inflows to the Refuge (total inflow discharge [acre-feet] was 460% of long-term mean). 2000 was a drought year with total inflow discharge (acre-feet) to the Refuge only 60% of long-term mean. Three sources of nutrient loading to the Refuge were quantified (inflows, atmospheric wet deposition, and snow goose excrement). Inflows contributed 99% of total nitrogen and 99% of total phosphorus to the refuge in 1999, and 84% and 99% respectively in 2000. Atmospheric deposition was not a contributor of total phosphorus in either year, and contributed 1% and 2% of the total nitrogen in 1999 and 2000, respectively. Snow goose excrement was an insignificant contributor of total phosphorus or total nitrogen in both years ($\leq$1%). During this investigation, exceedences of transboundary water quality objectives occurred downstream of the Refuge with no greater frequency then exceedences in inflows upstream of the Refuge, while concentrations in the Refuge pools were consistently lower than concentrations downstream of the Refuge. Possible explanations for downstream exceedences are discussed in the report. The total nitrogen/total phosphorus ratios indicate the Refuge pools are nitrogen limited, thus susceptible to blue-green algae blooms. Calculated trophic status indexes coupled with water quality data show the Refuge aquatic habitat as a whole is a boarder-line mesotrophic/eutrophic aquatic system. Nutrient fluxes from pool sediments to the above water column were calculated through in-situ isolation of sediments and corresponding water column. As dissolved oxygen decreased in the water column, large fluxes of dissolved phosphorus from the sediments were measured. The mean dissolved phosphorus release from sediments among the Refuge pools was nearly 60 mg/m^2/day. Under both a high-flow and low-flow year, the tributaries, Willow, Stone, and Boundary Creeks consistently had high concentrations of nutrients, ions, dissolved and suspended solids, and fecal coliforms. Water quality on the Refuge would likely improve with implementation of best management practices within the watersheds of these three tributaries.

ACKNOWLEDGEMENTS

Thanks are extended to Terri Thorn for assistance with field work; and the U.S. Geological Survey, Water Resources Division, Bismarck, ND, for sample collections. Manuscript reviewers included: Mike Sauer and Peter Wax, North Dakota Department of Health; and Meg Estep, U.S. Fish and Wildlife Service. Thanks also are extended to Mike Ell, North Dakota Department of Health, and the North Dakota State Chemistry Lab for their assistance with sample analysis and interpretation. Refuge staff provided storage locations for field equipment and allowed access to the wetlands and associated aquatic habitats found on the Refuge. This investigation was funded by the U.S. Fish and Wildlife Service's

Environmental Contaminants Program (Project ID: 62410-1261-6C18), with assistance for analytical costs provided by the North Dakota Department of Health, Water Quality Division.

INTRODUCTION

The Souris River is an international river originating in Canada's Saskatchewan Province. The river flows south into the State of North Dakota, eventually looping north through the U.S. Fish and Wildlife Service's J. Clark Salyer National Wildlife Refuge (Refuge) before flowing into the Province of Manitoba (Fig. 1). The Canada-United States Agreement for Water Supply and Flood Control in the Souris River Basin stipulates water quality objectives would be cooperatively developed by the two countries. In 1989, the Souris River Bilateral Water Quality Monitoring Group (Monitoring Group) was established in accordance with the above agreement. The Monitoring Group is comprised of representatives from Environment Canada, Manitoba Environment, Saskatchewan Environment, North Dakota Department of Health (NDDH), U.S. Geological Survey (USGS), and Environmental Protection Agency (EPA). Trans-boundary water quality objectives and a monitoring plan were finalized in 1992. Water quality sampling and gaging stations are maintained at the two international boundary water crossings; where the Souris River enters the U.S. near Sherwood, ND, and where the Souris River enters Canada near Coulter, MB. The monitoring plan is designed to identify water quality exceedences in the Souris River, and to aid various jurisdictions in initiating corrective measures sufficient to comply with the Boundary Waters Treaty of 1909, which sets out basic principles governing boundary water use and management between Canada and United States.

Water samples collected for the Monitoring Group on the Souris River downstream of J. Clark Salyer Refuge's managed impoundments have shown consistent exceedences for several water quality parameters: total phosphorus, sulfate, sodium, iron, total dissolved solids, pH, dissolved oxygen, and fecal coliforms. Results from previous studies in the literature directed this investigation's efforts toward assessing multiple sources and/or processes likely contributing to the above listed water quality exceedences: 1) major and minor inflows (Wax 1998, Malcom 1978), 2) atmospheric deposition (Angelo and Anderson 1982), 3) waterfowl excrement (Post et al. 1998), and 4) internal nutrient releases from pool sediments (LaBaugh 1989).

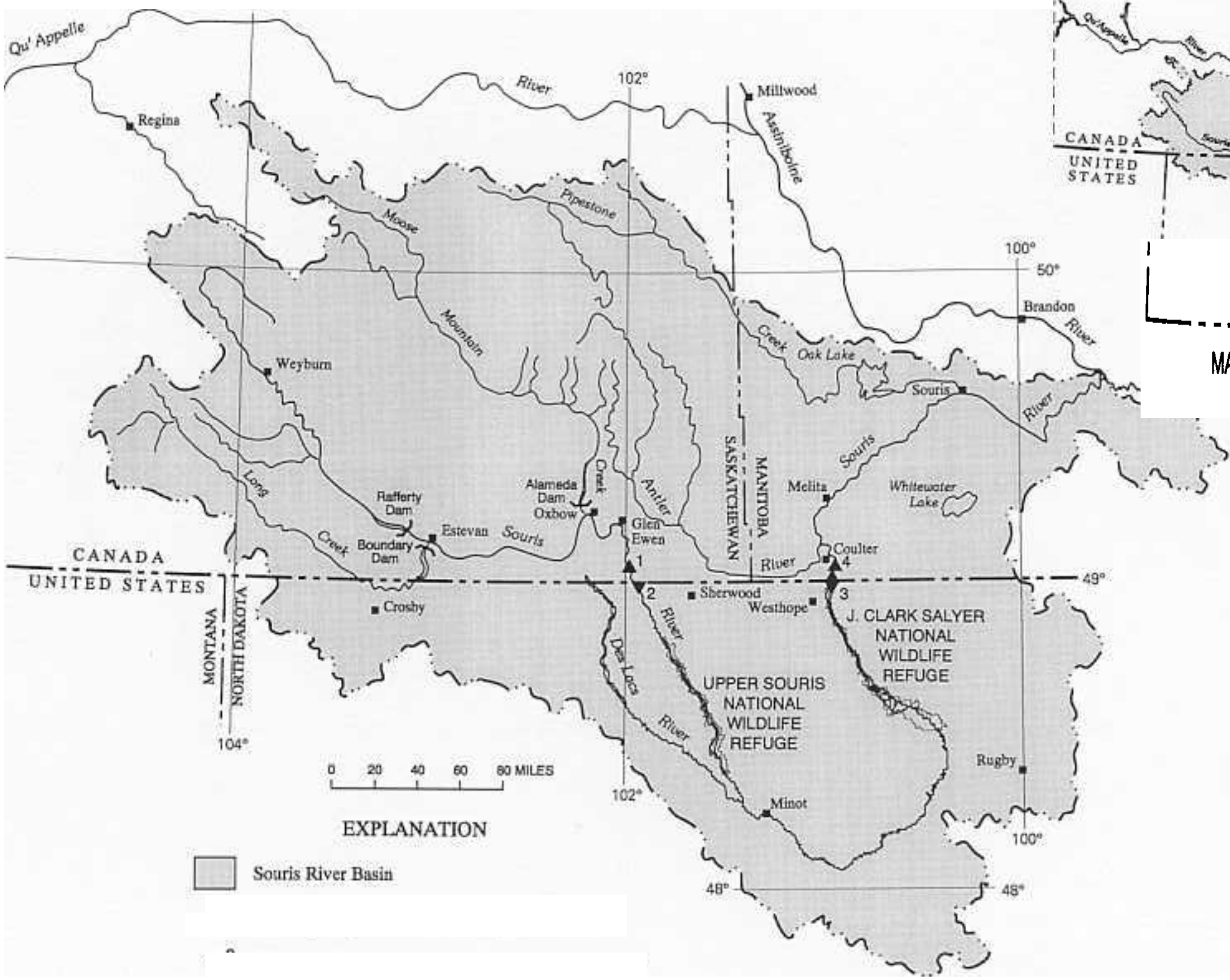
Excessive nutrient loading can lead to accelerated eutrophication and possible excess algal and macrophyte production within the Refuge's wetland ecosystem. Increased nutrients often result in extensive algae blooms, production of toxic blue-green algae, and, along with other factors, are believed to trigger outbreaks of avian botulism (Bell et al. 1955; Eklund & Dowell 1987; Friend 1987; Rosen 1971). Botulism has resulted in deaths of over 10,000 ducks, coots, and other migratory birds on the Refuge in some years. Eutrophication within Refuge impoundments also will severely limit the Refuge's ability to provide valuable wetland habitats for migratory bird production and migration.

The objectives of this investigation were to calculate a nutrient budget for the Refuge; identify primary sources of, and quantify nutrient loading; and evaluate methods to reduce loading to the system, subsequently improving Refuge habitat, trophic condition of Refuge pools, and possible downstream water quality. Field work for this investigation was conducted in 1999-2001.

STUDY AREA

The 58,700-acre J. Clark Salyer National Wildlife Refuge is administered by the U.S. Fish and Wildlife Service as part of a national network of wildlife refuges. The Refuge extends approximately 50 miles south from the North Dakota/Manitoba border in north-central North Dakota along the Souris River (Fig 2). Approximately 40 miles of free-flowing timbered river bottom and 35 miles of impounded river exist on the Refuge. The Refuge contains over 23,000 acres of managed marshes formed by construction of a series of five dikes and water control structures on the Souris River, which allow limited

Figure 1. Souris River Basin (Canada and United States) with location of J. Clark Salyer National Wildlife Refuge, North Dakota.



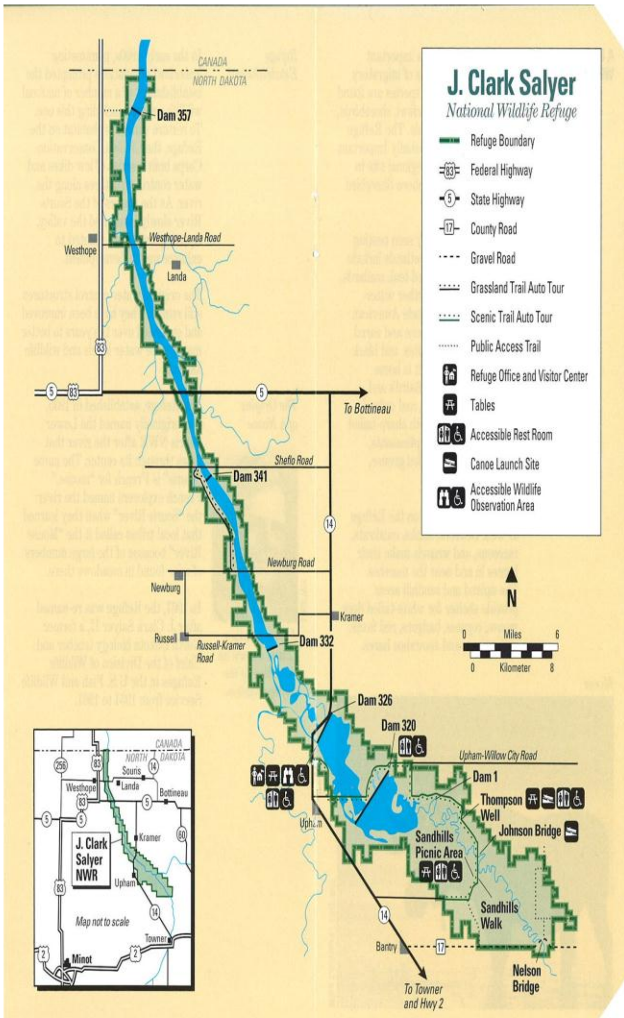


Figure 2. Map of J. Clark Salyer National Wildlife Refuge, North Dakota.

management of water resources. The approximate full supply levels (acre-feet storage) for each of the five pools are as follows: Pool 320 – 13,000 acre-feet; Pool 326 – 26,000; Pool 332 – 10,000; Pool 341 – 12,000; and Pool 357 – 19,000 acre-feet. The Refuge is an important production and migration staging area for waterfowl and other wetland dependent birds, providing key molting habitat for ducks from a wide local area. Exposed mudflats, shallow emergent wetlands, riverine oxbows, and open semipermanent water provide quality production and migration habitat for thousands of waterfowl. Fall migrating snow goose (*Chen caerulescens*) numbers can reach over 100,000 sustained for several weeks, and numbers of fall migrating ducks are greater than 500,000.

The Souris River is the Refuge's primary water source. Five lesser tributaries also supply water: Boundary Creek, Stone Creek, Deep River, Cut Bank Creek, and Willow Creek (Fig 3). Of the lesser tributaries, Willow Creek drains the largest area and Stone Creek the smallest (Table 1). Souris River flows are highly regulated through several impoundments in Canada: Boundary, Rafferty, and Alameda Reservoirs; and impoundments in the United States on Upper Souris, Des Lacs, and J. Clark Salyer Refuges in North Dakota (Fig 1).

The Souris River Basin encompasses over 24,000 square miles; approximately 17,000 square miles (71%) of the basin makes up the Refuge's watershed. Agricultural use dominates the Refuge's watershed. Over 80 percent of the Souris River watershed in North Dakota is devoted to cropland, rangeland, and pastureland (Table 1). Dry-land small grains and oil seeds are the dominant crops. Seven major agricultural drainage projects covering over 500 square miles in North Dakota discharge to the Refuge via several of the lesser tributaries.

METHODS

A chemical mass-balance calculation is expressed as:

$$\Delta (M) = \sum (I) - \sum (O)$$

Where $\Delta (M)$ is change of mass of a particular parameter in solution,

$\sum (I)$ is sum of inputs of the parameter, and

$\sum (O)$ is sum of outputs of the parameter.

A diagnostic mass-balance, in addition to the above calculation, quantifies sources of those parameters, thus determining if all the important

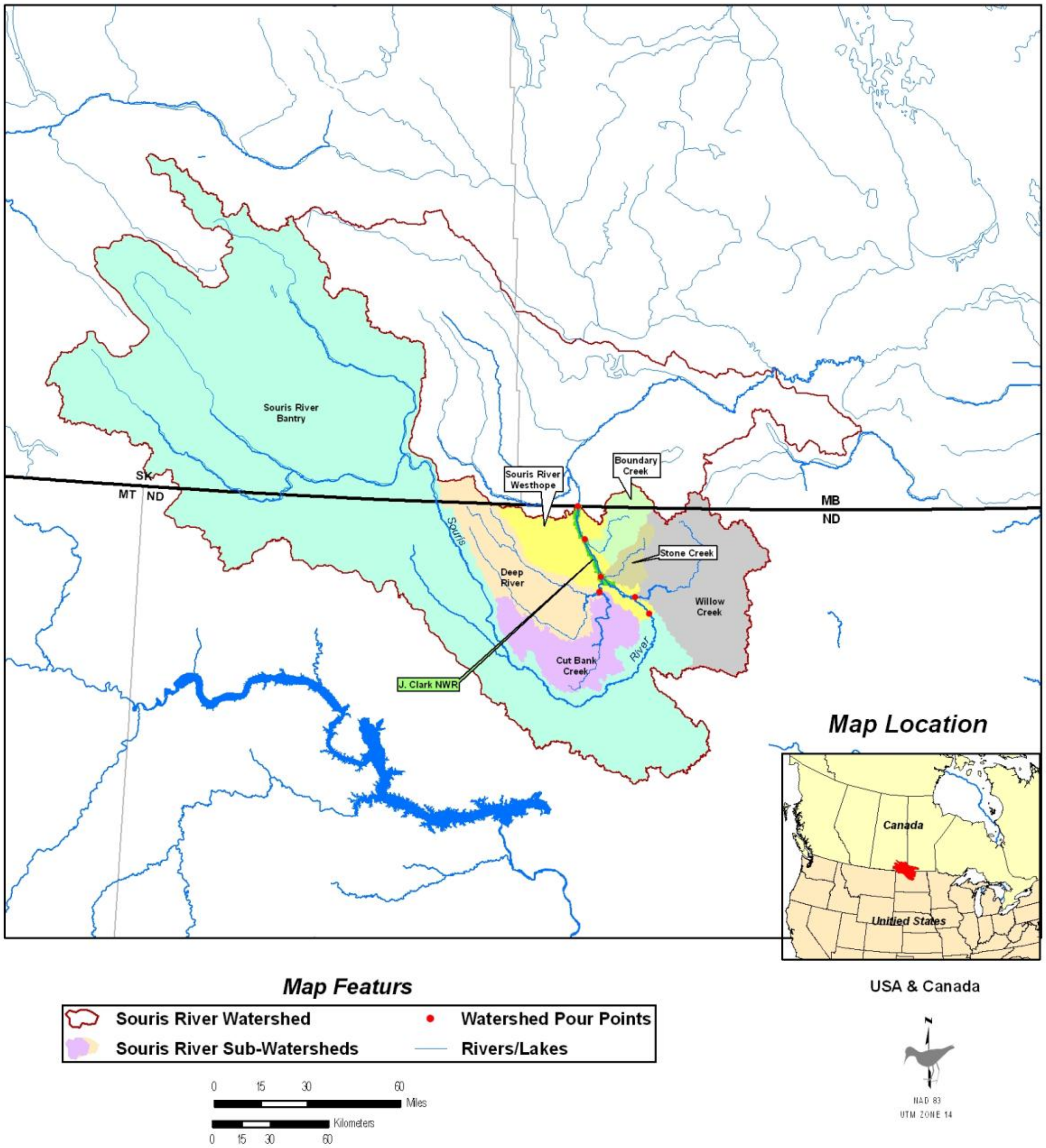


Figure 3. Select Souris River Sub-Watersheds of J. Clark Salyer National Wildlife Refuge, ND.

Table 1. Land-use and associated acreages for watersheds of J. Clark Salyer NWR, North Dakota.

Land-use	Souris River – Bantry[a]	Willow Creek	Deep River	Cut Bank Creek	Souris River– Westhope	Boundary Creek	Stone Creek
	United States Portion of Watersheds						
Cropland	1,668,625	398,868	389,797	259,154	260,329	90,846	76,906
Grassland	365,409	189,653	76,905	79,922	47,418	12,156	9,649
Prairie	544,172	150,806	65,634	100,754	57,003	9,930	6,099
Shrubland	27,339	1,148	41	96	136	111	15
Woodland	55,880	94,330	2,150	3,353	8,222	8,835	3,043
Wetland	291,799	122,978	34,725	44,209	45,425	7,836	7,480
Developed/Barren	30,714	10,516	1,480	6,538	924	484	676
US Subtotal (acres)	2,983,937	968,298	570,733	494,025	419,457	130,198	103,868
	Canadian Portion of Watersheds						
Cropland	3,786,198	None	58,099	None	91	26,849	None
Shrubs	175,746	None	4,315	None	None	None	None
Forage	56,024	None	None	None	None	1,235	None
Grassland	760,846	None	None	None	None	8,321	None
Trees	44,660	12,188	None	None	None	12,011	None
Wetlands	67,176	7,145	None	None	None	110	None
Developed/Barren	54,424	None	None	None	None	None	None
Canada Subtotal (acres)	4,945,074	19,333	62,414	None	91	48,527	None
Total	7,929,011	987,631	633,147	494,025	419,548	178,725	103,868

[a] See Figure 3 for description of individual watersheds.

mass-transfer processes occurring in a system have been identified. The sources quantified in this investigation include atmospheric wet deposition, waterfowl, inflows, and internal cycling.

Atmospheric Wet Deposition

Monthly precipitation totals for years 1999 and 2000 were obtained from the National Weather Service, Bismarck, ND. The National Weather Service maintains precipitation data collected at the Refuge headquarters, near the town of Upham on the southern end of the Refuge, and precipitation collected at the town of Westhope, near the northern end of the Refuge.

Mean monthly precipitation-weighted nutrient concentration data were obtained from the National Atmospheric Deposition Program/National Trends Network (NADP/NTN). The NADP/NTN is a nationwide network of precipitation monitoring sites which collect data on the chemistry of precipitation. Mean monthly concentrations (mg/L) of nutrients (NH_4, and NO_3) and ions (SO_4, and Na) in wet deposition were calculated from measurements collected at two NADP/NTN sites in North Dakota: Icelandic State Park in Pembina County and Woodworth Station in Stutsman County (Fig 4). Although these two sampling sites are geographically distant from the Refuge, their collections are accurate representations of concentrations in wet deposition throughout the state (pers. comm., D. Harmon, NDDH, Division of Air Quality).

Mean monthly deposition (kg/ha) of each parameter was determined by multiplying their respective mean monthly concentrations (mg/L) by monthly precipitation totals (cm) and dividing by 10. Total nutrient and ion loading to the Refuge via wet deposition was then estimated by multiplying the above calculated deposition (kg/ha) with surface area (ha) for each of the Refuge's five pools. Precipitation totals measured at Upham were used to calculate loading to Refuge pools 320, 326, and 332.

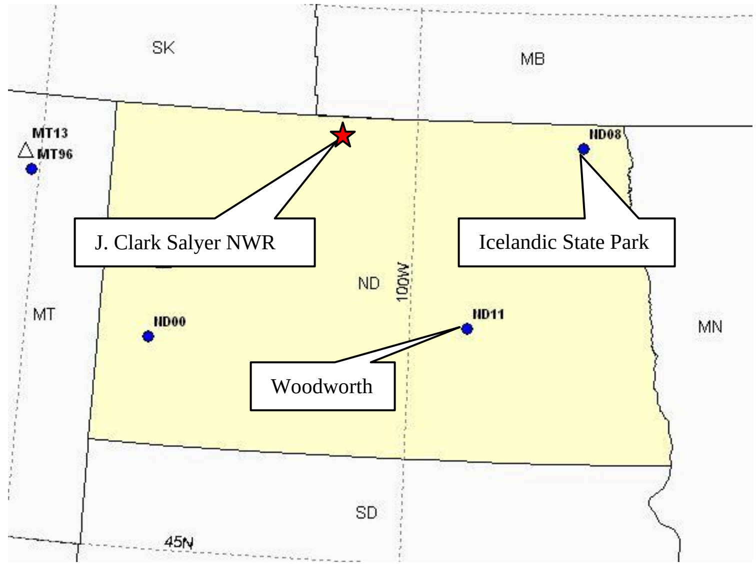


Figure 4. Locations of two National Atmospheric Deposition Program stations in North Dakota.

Precipitation totals measured at Westhope were used to calculate loading to pool 357. Pool 341 is situated halfway between Upham and Westhope, thus the average of combined precipitation data from Upham and Westhope was used to calculate loading to pool 341.

Waterfowl Nutrient Loading

Daily behaviors of lesser snow goose flocks were monitored weekly during the 2000 fall migration to estimate time and energy budgets for geese using the Refuge. The first day of weekly observations began around 1500 hours with two observers (one each on the north and south half of Refuge) scanning Refuge pools for a large group ($\geq$500 individuals) of loafing geese. When a large group was found, they were observed with field glasses from a vehicle at a distance that would not influence their behavior. Time and direction of flight were recorded when the first birds from the observation flock began to lift and leave the Refuge for an evening feeding bout. Time was recorded when the last of the observation flock had departed for the evening feeding. This last group of geese was followed in the vehicle to their feeding location. The location was noted on a map and then observers returned to the Refuge and waited for geese to return from their evening feeding bout. Time was recorded when the first group of birds began returning until flocks were no longer observed returning.

The next morning observers returned to the Refuge around 0645 to observe pools where large groups of geese had roosted the previous night. Time and direction of flights were recorded when birds began and finished leaving the Refuge for their morning feeding bouts. As in the evening observations, a focal flock was followed to its feeding location and noted on a map.

Observers then visited feeding locations from the previous evening and collected fecal samples. Fecal samples were only collected if the site was not currently occupied by morning feeding geese and with landowner permission. Fecal collections were made by randomly walking through the area where birds were observed feeding the night before. Fecal material was collected with a gloved hand and placed in a plastic bag. Crop residue and other extraneous materials were removed from each fecal sample prior to placement in plastic bag. Bags were labeled and placed on dry ice. The type of food geese had been feeding on was recorded.

Observers then returned to the Refuge to wait for geese to return from their morning feeding bouts. The time was recorded when the first and last birds arrived. Fecal samples were collected from the morning feeding locations after geese were no longer observed returning to the Refuge. Observers returned to the Refuge at about 1500 to begin the process over. Fecal samples were submitted to the NDDH State Chemistry Laboratory for nutrient analysis (total phosphorus [P], Kjeldahl nitrogen, $NO_2 + NO_3$, and total nitrogen [N]).

Since 1992, Refuge staff has been estimating population numbers of snow geese using the refuge during fall migration and submitting those estimates for the Service's North Dakota Weekly Waterfowl Migration Updates. These weekly updates were used to estimate average goose arrival/departure dates and peak population numbers on the Refuge.

Nutrient (Nitrogen and Phosphorus) loading from geese to the Refuge was estimated with a model that linked lesser snow goose bioenergetics to daily time budgets, food type, feeding behaviors, and Refuge goose population estimates (Post et al. 1998). Daily energy expenditure for any living organism dictates the amount of energy intake needed to maintain existence metabolism. Energy intake is directly related to energy content of food consumed. And the amount and type of food ingested directly affects amount of waste material defecated.

The avian bioenergetics models (Kendeigh et al. 1977, Nagy et al. 1999) were used to estimate the daily energy expenditure for a 2.6 kg goose (Bellrose 1980, Post et al. 1998) during fall migration. The models take into account a bird's basal metabolism, routine metabolism of free-living birds, and flight during various times of the year. Weight gains during fall migration are typically from increase in fat storage (Mowbray et al. 2000) and thus geese are not storing N or P.
Consequently, similar to Post et al. (1998), it was assumed geese were at equilibrium with respect to N and P.

The mass of nutrients excreted per bird was calculated from mass of excreted material and concentrations of N and P in excreta. Mass of excreted material per bird was calculated based on the digestive efficiency (DE) of snow geese:

$$DE = (Qi - Qe)/Qi$$

where Qi and Qe equal, respectively, the food intake rate and excreta production rate (g/day). Thus:

$$Qe = Qi - (Qi \times DE)$$

This represents total amount of material excreted by a goose, not the amount loaded to the Refuge pools. The mass loaded to Refuge pools was calculated as a function of total material excreted, gut clearance rate of food ingested, and time spent on and off the Refuge.

Inflow and Pool Water Sampling

Surface water samples were collected from the main-stem Souris River, five tributaries and all five Refuge pools (Fig 5) during 1999 and 2000. Samples were collected by the USGS, Water Resources Division Bismarck, ND. Sampling protocol followed USGS standard techniques of water-resources investigations (Buchanan and Somers 1969, Guy and Norman 1970, Wilde and Radtke 1998). Inflow water quality samples were collected at least once per month April – November. Pool water quality samples were collected at least once per month April – October. All samples were sent to the NDDH State Chemistry Laboratory for analysis.

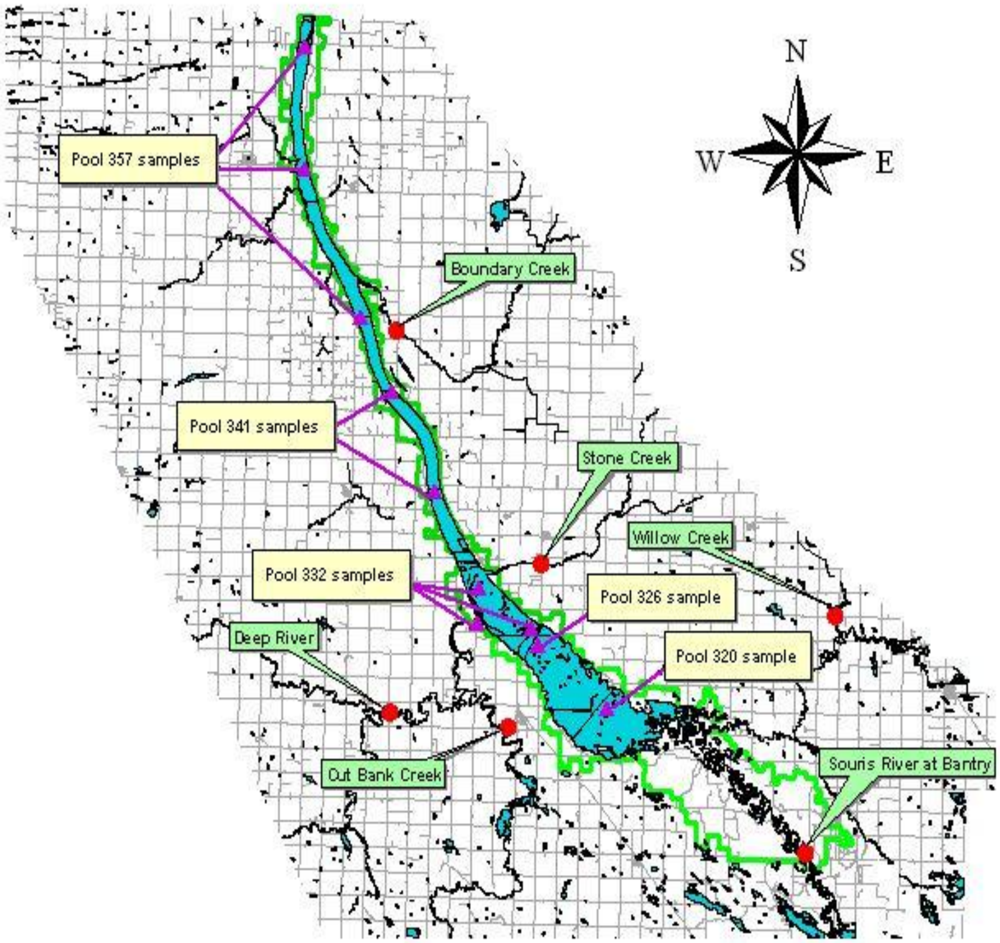


Figure 5. Inflow and Pool sampling locations, J. Clark Salyer NWR, North Dakota, 1999-2000

Gaging stations were established on the six inflow systems and maintained by the USGS. Discharge measurements were collected daily over the 2-year period. Environment Canada maintains a gaging station on the Souris River near Coulter, Manitoba, (approximately 6 miles downstream of U.S./Canada boarder). Results of water quality analysis and discharge measurements for this site were obtained from Environment Canada.

The suite of analyzed and measured parameters in water quality samples (Table 2) conforms to current monitoring efforts of the Bilateral Monitoring Group at the two border crossings on the Souris River near Sherwood and Coulter, MB.

Table 2. Water quality parameters measured in inflows and refuge pool water samples, J. Clark Salyer NWR, North Dakota 1999-2000.

Metals (ug/L)	**Nutrients (mg/L)**
Arsenic	Nitrate/Nitrite as N
Aluminum	Nitrogen (total)
Barium	Kjeldahl Nitrogen (total)
Boron	Ammonia as N
Beryllium	Phosphorus (total)
Cadmium	Phosphorus (dissolved)
Chromium	
Cobalt	**Physical**
Copper	Conductivity (umhos/cm)
Iron	pH
Lead	Temperature (C)
Molybdenum	Dissolved Oxygen (mg/L)
Nickel	Hardness (total) (mg/L)
Selenium	Total Dissolved Solids (mg/L)
Zinc	Total Suspended Solids (mg/L)
Ions (mg/L)	Fecal Coliform (#/100 ml)
Chloride	Chlorophyll a (ug/L)
Sodium	
Sulfate	

Estimates of nutrient loads were calculated using the U.S. Army Corps of Engineers' FLUX model (Walker 1998). FLUX estimates loadings of nutrients, or other water quality parameters, passing a stream's sampling point over a given period of time. Data requirements to run the model computations include: 1) grab-sample parameter concentrations for a period of at least 1 year, 2) corresponding flow measurements (instantaneous or daily mean values), and 3) a complete flow record (mean daily flows) for the period of interest.

FLUX extrapolates the flow/concentration relationship from the sample record to the entire flow record and produces a total mass discharged. The mass discharge and subsequent loading estimates are calculated using six calculation methods, with uncertainty characterized by error variances (CV). The CV equals standard error of mean loading divided by mean loading. In practice, selecting the "best" calculation method and loading estimate is associated with the least amount of CV.

Where sample data is adequate (i.e., sample concentrations varied systematically with sample flows), FLUX includes an option to divide or "stratify" the flow and concentration data into a series of groups and calculate loadings separately within each group. Stratification results in lower variance for the total loading estimate.

Trophic condition of the Refuge pools was calculated to assess their productivity. The NDDH routinely uses a Trophic Status Index (TSI) developed by Carlson (1977) to delineate productivity of North Dakota lakes and reservoirs. Carlson's TSI uses a mathematical relationship based on three indicators: secchi disk transparency in meters, surface total phosphorus in µg/L, and chlorophyll-a in µg/L. A TSI is calculated for each of the three indicators using the following equations:

Trophic status based on secchi disk (TSIS):

$$TSIS = 60 - (14.41*[\ln (SD)])$$

Where SD = Secchi disk transparency in meters.

Trophic status based on total phosphorus (TSIP):

$$TSIP = (14.20*[\ln (TP)]) + 4.15$$

Where TP = Total phosphorus concentration in ug/L.

Trophic status based on chlorophyll-a (TSIC):

$$TSIC = (9.81*[\ln (TC)]) + 30.60$$

Where TC = Chlorophyll-a concentrations in µg/L.

The three indicator TSI's are then averaged to provide an overall TSI and this numerical value then corresponds to a trophic condition ranging from 0 to 100, with increasing values indicating a more eutrophic condition (Table 3). Carlson's TSI was developed for lakes, primarily phosphorus limited; however, most North Dakota lakes and reservoirs are nitrogen limited, having an abundance of phosphorus (Wax 2005). Any of the three variables of the TSI can theoretically be used to classify a given waterbody. Priority is given to chlorophyll because this variable is the most accurate of the three at predicting algal biomass. The index is predicated on the idea that it is predicting algal biomass (Carlson 1983). Although transparency and phosphorus may co-vary with trophic state, the changes in transparency are caused by changes in algal biomass and total phosphorus may or may not be strongly related to algal biomass.

Table 3. Carlson's Trophic State Index[a] used to classify trophic state of impoundments on J. Clark Salyer NWR, North Dakota, 1999-2000.

		Range of concentrations &/or depth typically found for each respective TSI		
Trophic State Index (TSI) Scale	**Lake Classification[b]**	**Total Phosphorus (ug/L)**	**Chlorophyll-a (ug/L)**	**Secchi (m)**
0	Oligotrophic	0.75	0.04	64
10	Oligotrophic	1.5	0.12	32
20	Oligotrophic	3	0.34	16
30	Oligotrophic	6	.094	8
40	Mesotrophic	12	2.61	5
50	Eutrophic	24	7.23	2
60	Eutrophic	48	20	1
70	Hypereutrophic	96	55.5	0.5
80	Hypereutrophic	192	154	1.25
90	Hypereutrophic	384	426	1.025
100	Hypereutrophic	768	1180	0.0625

[a] Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography. 22:361-369.
[b] Lakes can generally be classified in order of increasing productivity as Oligotrophic (TSI = 0-39), Mesotrophic, (TSI = 40-49), Eutrophic (TSI = 50-69), or Hypereutrophic (TSI = 70-100).

<u>**Internal Cycling**</u>

Due to weather and mechanical problems, nutrient data from pool sediments was collected only during June and July in 2001. In-situ water samples were collected from each pool during June 11-15 and July 23-27 to determine amounts of nutrients fluxed from pool sediments to the overlying water column. Two sites per pool (only one site for pool 341) were randomly selected (Fig. 6). At each site, a capped, polyvinyl chloride (PVC) pipe (30.5 cm ID x 183 cm length) was driven vertically 25-30 cm into sediments as a means to isolate sediments and associated overlying water column from external forces such as wind/wave action, light/algae production, and precipitation. Zip-ties were used to attach the PVC pipe to a metal T-post and maintain its vertical position (Fig. 7).

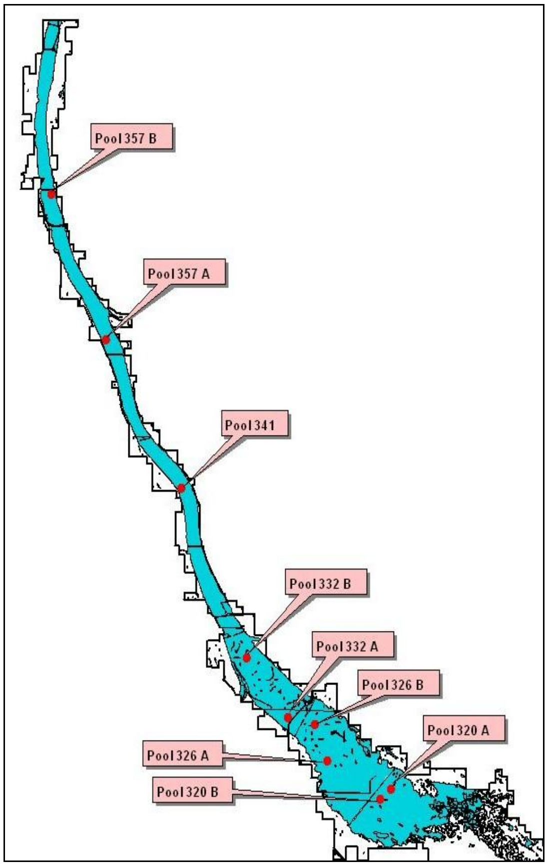


Figure 6. Locations of in-situ sediment sampling sites on J. Clark Salyer NWR, North Dakota, 2001.

Figure 7. Photograph of PVC tube used in sampling nutrient flux from pool sediments on J. Clark Salyer NWR, North Dakota, 2001.

Prior to erecting the tubes and any disturbance of sediments, surface water samples were collected at each site using a clean Kemmerer. 500 ml of the water sample was placed in a clean Nalgene container, preserved with 2 ml of sulfuric acid, and placed on ice. A peristaltic pump was used to draw 250 ml of the remaining sample through a clean 50 mm diameter membrane filter (0.45 um pore size). The filtered sample was preserved with 2 ml of sulfuric acid and placed on ice. Temperature, DO, specific conductance, and pH were also recorded using hand-held meters. PVC tubes were then installed and left to settle for 24 hours. All samples were analyzed at the NDDH State Chemistry Laboratory. Analysis was performed for dissolved P, total P, ammonia, NO_2+NO_3, Kjeldahl N, and total N.

Over the next 4 days, tube sites were visited and water samples outside the tubes were sampled as before. Depth of water column inside the tubes was determined; the water column was stirred slightly (efforts were taken to not upset and suspend sediments); hand-held meters recorded temperature, dissolved oxygen (DO), specific conductance, and pH inside the tube; and then a water sample was also collected from inside the tube using a clean Kemmerer (Fig. 8). Water samples from inside and outside the tubes were labeled and filtered accordingly, preserved with acid, and chilled. After 5 days of deployment in June, the tubes were removed (T-posts remained in place). In July, tubes were again installed for another 5 days of sampling. In July, tubes were driven into sediments on the opposite side of the T-post from the June sampling event.

Figure 8. Photograph of water column sample collection with Kemmerer inside of in-situ tube,

J. Clark Salyer NWR, North Dakota, 2001.

RESULTS

Atmospheric Wet Deposition

Total yearly precipitation at Upham was greater in 2000 than 1999, and nearly identical both years at Westhope (Table 4). Yearly totals at Upham in 1999 and 2000 were 132% and 157% of normal, respectively, and 146% and 147% of normal, respectively, at Westhope. Average concentrations (mg/L) of nutrients and ions in precipitation measured in 2000 were typically higher than in 1999 (Table 5).

Table 4. Monthly precipitation totals measured at Upham and Westhope, North Dakota, 1999-2000.

Upham			Westhope		
Month	**1999 Precipitation (cm)**	**2000 Precipitation (cm)**	**Month**	**1999 Precipitation (cm)**	**2000 Precipitation (cm)**
January	0.93	0.29	**January**	1.16	0.25
February	0.56	1.04	**February**	0.29	0.92
March	0.98	0.82	**March**	1.02	0.56
April	0.96	1.06	**April**	0.67	1.15
May	7.77	2.63	**May**	7.87	2.91
June	2.64	6.64	**June**	1.80	3.57
July	4.03	3.81	**July**	5.90	4.42
August	1.64	3.72	**August**	1.33	2.73
September	2.03	1.61	**September**	2.12	2.04
October	0.12	0.62	**October**	0.18	0.98
November	0.11	3.22	**November**	0.09	2.70
December	0.26	0.61	**December**	0.23	0.53
Total	22.03	26.07	**Total**	22.66	22.76

Table 5. Monthly average concentrations of parameters measured in wet deposition at National Atmospheric Deposition Program sites in North Dakota, 1999-2000.

	1999				2000			
Month	**NH_4 (mg/L)**	**NO_3 (mg/L)**	**SO_4 (mg/L)**	**Na (mg/L)**	**NH_4 (mg/L)**	**NO_3 (mg/L)**	**SO_4 (mg/L)**	**Na (mg/L)**
January	0.16	0.97	0.31	0.01	0.07	0.20	0.07	0.01
February	0.48	1.46	0.85	0.03	0.40	0.70	0.47	0.02
March	0.50	1.57	1.01	0.05	0.98	1.89	1.34	0.04
April	0.40	0.73	0.58	0.08	0.79	1.30	0.98	0.03
May	0.76	1.35	1.04	0.03	0.81	1.23	0.70	0.03
June	0.69	1.36	0.80	0.05	0.53	0.99	0.60	0.02
July	0.55	1.04	0.63	0.03	0.74	1.30	0.64	0.03
August	0.37	0.85	0.53	0.02	0.69	1.20	0.85	0.03
September	0.41	0.60	0.53	0.02	0.69	1.54	1.08	0.02
October	0.62	0.90	0.80	0.02	0.34	0.75	0.42	0.06
November	0.54	2.05	1.77	0.04	0.44	1.55	5.73	2.06
December	0.33	1.20	0.52	0.05	0.05	0.39	0.08	0.01
Yearly Mean	0.48	1.17	0.78	0.04	0.54	1.08	1.08	0.20

The following formula was used to calculate monthly deposition in kg/ha for NH_4, NO_3, SO_4, and Na:

$$\text{Deposition (kg/ha)} = \frac{\text{Precipitation (cm)} \times \text{Concentration (mg/L)}}{10}$$

Total yearly deposition (kg/ha) for all parameters was greater in 2000 compared to 1999 (Table 6), and atmospheric loading to the Refuge for all parameters was greater in 2000 than 1999 (Table 7).

Table 6. Calculated monthly, and yearly total wet deposition (kg/ha)[a] of parameters in precipitation at Upham and Westhope, North Dakota, 1999-2000.

	1999				2000			
	NH_4 (kg/ha)	NO_3 (kg/ha)	SO_4 (kg/ha)	Na (kg/ha)	NH_4 (kg/ha)	NO_3 (kg/ha)	SO_4 (kg/ha)	Na (kg/ha)
Upham								
January	0.01	0.09	0.03	0.00	0.00	0.01	0.00	0.00
February	0.03	0.08	0.05	0.00	0.04	0.07	0.05	0.00
March	0.05	0.15	0.10	0.00	0.08	0.15	0.11	0.00
April	0.04	0.07	0.06	0.01	0.08	0.14	0.10	0.00
May	0.59	1.05	0.81	0.02	0.21	0.32	0.18	0.01
June	0.18	0.36	0.21	0.01	0.35	0.65	0.40	0.01
July	0.22	0.42	0.25	0.01	0.28	0.49	0.24	0.01
August	0.06	0.14	0.09	0.00	0.25	0.44	0.32	0.01
September	0.08	0.12	0.11	0.00	0.11	0.25	0.17	0.00
October	0.01	0.01	0.01	0.00	0.02	0.05	0.03	0.00
November	0.01	0.02	0.02	0.00	0.14	0.50	1.85	0.66
December	0.01	0.03	0.01	0.00	0.00	0.02	0.00	0.00
Total	1.28	2.54	1.74	0.07	1.58	3.10	3.45	0.72
Westhope								
January	0.02	0.11	0.04	0.00	0.00	0.01	0.00	0.00
February	0.01	0.04	0.02	0.00	0.04	0.06	0.04	0.00
March	0.05	0.16	0.10	0.00	0.05	0.11	0.08	0.00
April	0.03	0.05	0.04	0.01	0.09	0.15	0.11	0.00
May	0.59	1.06	0.82	0.02	0.24	0.36	0.20	0.01
June	0.12	0.24	0.14	0.01	0.19	0.35	0.21	0.01
July	0.32	0.61	0.37	0.02	0.33	0.57	0.28	0.01
August	0.05	0.11	0.07	0.00	0.19	0.33	0.23	0.01
September	0.09	0.13	0.11	0.00	0.14	0.31	0.22	0.00
October	0.01	0.02	0.01	0.00	0.03	0.07	0.04	0.01
November	0.00	0.02	0.02	0.00	0.12	0.42	1.55	0.56
December	0.01	0.03	0.01	0.00	0.00	0.02	0.00	0.00
Total	1.31	2.58	1.76	0.07	1.41	2.76	2.98	0.61

[a] Deposition (kg/ha) = Precipitation (cm) x Concentrations (mg/L)

Table 7. Amounts of select parameters loaded via atmospheric wet deposition to individual pools on J. Clark Salyer NWR, North Dakota, 1999 & 2000.

		1999				2000			
Pool #	**Pool Size[a] (ha)**	**NH_4 (kg)**	**NO_3 (kg)**	**SO_4 (kg)**	**Na (kg)**	**NH_4 (kg)**	**NO_3 (kg)**	**SO_4 (kg)**	**Na (kg)**
320	2,621	3,354	6,664	4,557	179	4,141	8,128	9,053	1,891
326	2,643	3,382	6,720	4,595	180	4,175	8,196	9,129	1,907
332	2,205	2,822	5,606	3,833	150	3,483	6,838	7,616	1,591
341	1,504	1,945	3,853	2,629	101	2,251	4,405	4,835	1,002
357	2,623	3,427	6,770	4,611	174	3,708	7,230	7,804	1,603
Total		14,930	29,613	20,225	784	17,758	34,797	38,437	7,994

[a] Pool size at full pool capacity.

The NADP/NTN detection limit for ortho-phosphate is 3.0 ppb. Only 9 of 170 samples collected from the two NADP sites in ND during 1999 and 2000 were at, or slightly above, detection limits (pers. comm. V. Bowersox, NADP/NTN). Six of these nine samples were considered “contaminated” from allochthonous organic debris. Thus, wet deposition is not considered to be a contributor of phosphorus to the aquatic systems on the Refuge during this investigation.

Waterfowl Nutrient Loading

Population Trends - Snow geese begin arriving on the Refuge from their northern breeding grounds the last week in September and are generally gone from the Refuge by the third week of November (Fig 9). Arrival and departure dates during the fall migration season are dependant mostly upon weather. Peak populations of snow geese on the Refuge typically occur during the last week of October and first week of November.

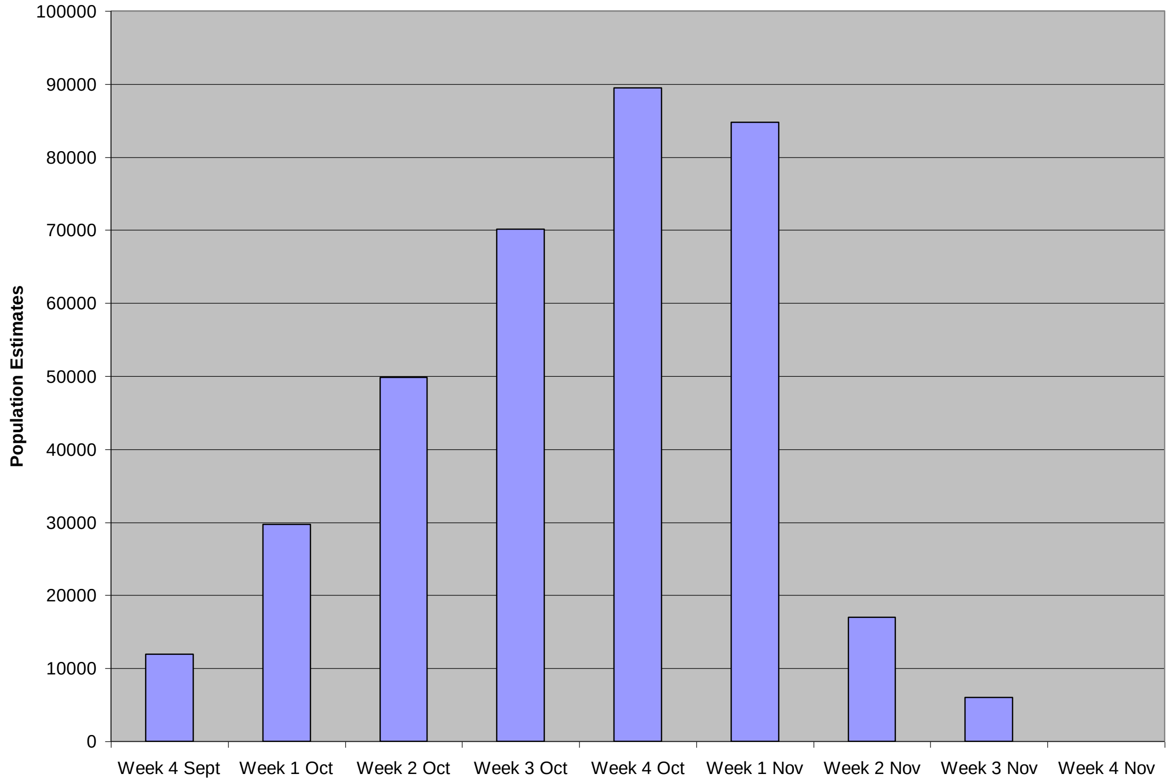


Figure 9. Average weekly population estimates of snow geese (*Chen caerulenses*) using J. Clark Salyer NWR, North Dakota, during fall migration in years 1992 thru 2006.

Over a 15-year period (1992-2006), the largest estimated population of fall migrating snow geese using the Refuge occurred in 1994. That year, an average of 123,750 snow geese were present each week (n=8 weeks) from late September to late November (Table 8). Population estimates were lowest in 2006 (2,625 geese per week). The low numbers were attributed to low water levels and an early freeze-up (pers. comm. G. Erickson. J. Clark Salyer Refuge). During 1999 and 2000, respectively, an estimated 23,375 and 52,563 geese were present each week during fall migration.

Table 8. Weekly population estimates of snow geese (*Chen caerulescens*) on J. Clark Salyer NWR, North Dakota, during fall migrations, 1992-2006.

Year	Week 4 September	Week 1 October	Week 2 October	Week 3 October	Week 4 October	Week 1 November	Week 2 November	Week 3 November	Average #/week (n=8)
1992	20,000	60,000	90,000	150,000	167,000	40,000	0	0	65,875
1993	10,000	100,000	100,000	150,000	150,000	90,000	0	0	75,000
1994	100,000	150,000	200,000	100,000	70,000	300,000	70,000	0	123,750
1995	30,000	60,000	60,000	60,000	100,000	200,000	0	0	63,750
1996	500	10,000	40,000	60,000	80,000	260,000	0	0	56,313
1997	0	15,000	35,000	50,000	200,000	40,000	10,000	0	43,750
1998	15,000	25,000	27,000	40,000	50,000	35,000	0	0	24,000
1999	1,000	3,000	3,000	40,000	40,000	100,000	0	0	23,375
2000	500	5,000	50,000	100,000	120,000	120,000	25,000	0	52,563
2001	1,000	15,000	20,000	50,000	5,000	1,000	0	0	11,500
2002	0	1,000	80,000	160,000	200,000	0	0	0	55,125
2003	0	0	40,000	70,000	100,000	0	0	0	26,250
2004	500	500	1,000	1,000	40,000	60,000	100,000	80,000	35,375
2005	100	500	500	500	20,000	25,000	50,000	10,000	13,325
2006	100	300	500	20,000	100	0	0	0	2,625

Local Migration Patterns and Feeding Behavior - Geese demonstrated consistent, daily migration patterns during the fall of 2000. They left the Refuge at dawn to feed in nearby harvested agricultural fields, returning at midday. They again left the Refuge late afternoon to feed, returning at dusk. Geese loafed and roosted mainly on the northern and southern ends of pool 357, middle of pool 341, and on pool 320.

The average time (hours) per day geese spent off and on the Refuge, respectively, was 7.8 hrs and 16.2 hrs. Geese were off the Refuge 5.25 hours during morning feeding bouts, and off the Refuge 2.6 hours during evening feeding. The time period from when the first flock of birds left a roosting group until all birds from that group had left a pool to feed in the morning ranged from 15-25 minutes. And the time for a group of loafing birds to leave for the evening feeding bout ranged from 60-90 minutes. Conversely, the time period for when the first birds began returning to loaf/roost after their morning and evening feeding bouts until all had returned took 60-90 and 20-45 minutes, respectively.

Snow geese were observed to feed exclusively in harvested fields of small grains (barley and wheat). The average distance an observed flock flew from its Refuge roost to a feeding site was 6.2 miles (n = 28, SE = 0.64) (Fig. 10). Observations and published information pertaining to flight speeds (Mowbray et al. 2000) suggest the geese spent approximately 30 minutes flying round-trip to and from feeding sites. Thus, time spent feeding was estimated to be 4.75 hrs in the morning (5.25 total hrs off Refuge minus 0.5 hrs flight time) and 2.1 hrs in the evening. Morning feeding bouts account for 69% of daily food intake, while 31% occurred in evening feedings.

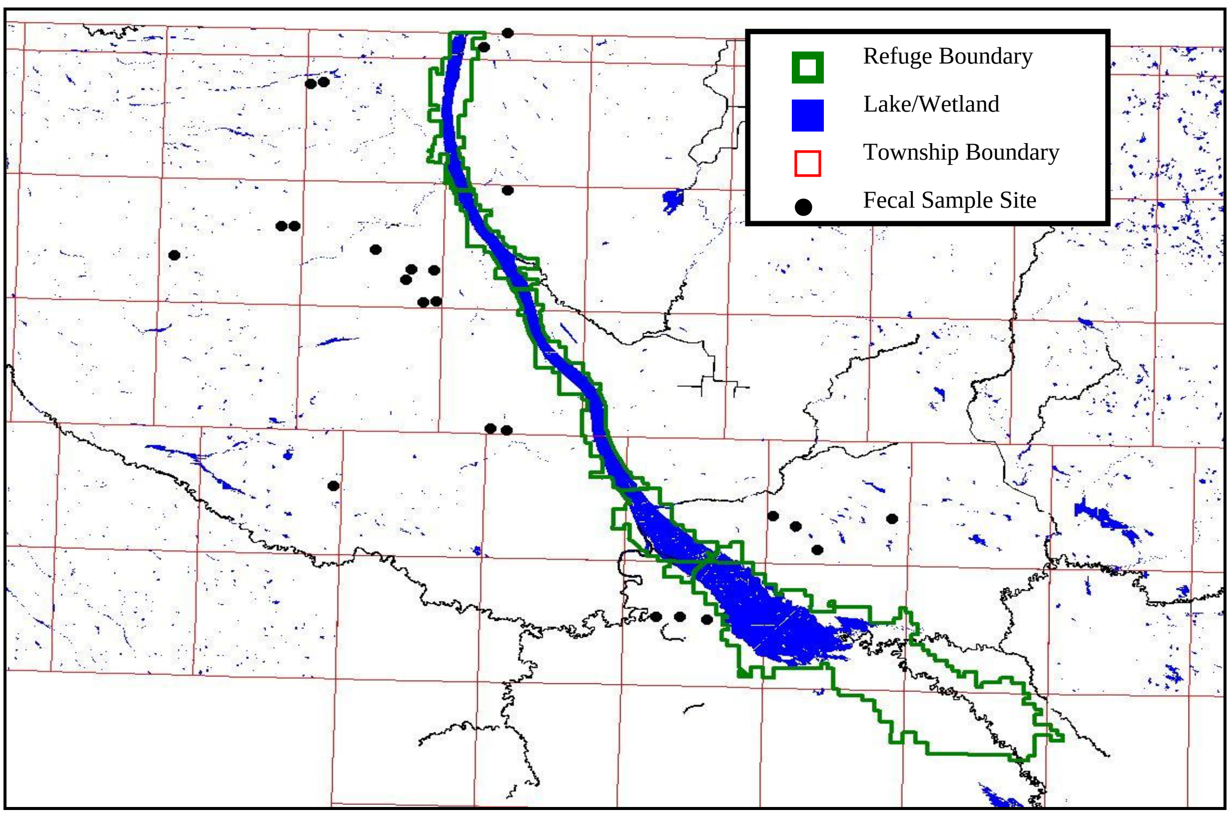


Figure 10. Locations of snow goose fecal sample sites around J. Clark Salyer NWR, North Dakota, 2000.

Excrement Production – A direct correlation exists between amount of excreta produced and amount of food intake (Karasov 1990). A 2.6 kg bird needs an estimated 134 g/day (dry wgt.) of small grains to maintain its energy needs, based on the following formula from Nagy et al. (1999):

$$I = \frac{DEE}{EC}$$

Where:

I = Ingested amount (g/day) needed to maintain a daily energy budget
DEE = Daily Energy Expenditure (Kj/day)
EC = Energy Content of food (Kj/g)

EC is further defined as: GE x DE, where GE = Gross Energy (Kj/g) of ingested food and DE = Digestive Efficiency of an animal feeding on that food. Gross Energy of small grains is 18 Kj/g (Bedard & Gauthier 1989; Karasov 1990), and the DE of snow geese feeding on small grains is 68% (Bedard and Gauthier 1989, Mowbray et al. 2000, Karasov 1990). The EC is then calculated as: 18 Kj/g x 0.68 = 12.24 Kj/g.

The average weight of an adult lesser snow goose is approximately 2.6 kg (Bellrose 1980, and Post et al. 1998). The DEE of a 2.6 kg bird is 1640 Kj/day (Frederick and Klaas 1982, Bedard and Gauthier 1989). Thus, the ingested amount (g/day) needed to maintain a daily energy budget for a snow goose is:

$$\frac{1640 \text{ Kj/day}}{12.24 \text{ Kj/g}} = 134 \text{ g/day of small grains}$$

Since 69% and 31% of daily food intake occurs during morning and evening feeding bouts, respectively, then 92.5 g of grain are consumed during morning feeding and 41.5 g are consumed per bird in the evening.

Excreta production is calculated based on food intake and the digestive efficiency (DE) of snow geese (Karasov 1990):

$$Q_e = Q_i - (Q_i \times DE)$$

where Q_e and Q_i equal, respectively, the excreta production and food intake (g/day, dry wgt.). Thus, the excreta production is 134 g/day – (134 g/day x 0.68) = 43 g/day. This breaks down to 29.7 and 13.3 g of fecal material excreted by a snow goose feeding on small grains during the morning and evening feeding bouts, respectively.

Not all of the fecal material produced by a goose is deposited on the Refuge. Snow geese have a fast food transit time in the gut and mean gut retention time for small grains is 3.1 hrs (Manseau and Gauthier 1993, Bedard and Gautheir 1986, Karasov 1990, Ankney 1977, and Hupp et al. 1996). Thus, the amount actually deposited on the Refuge is a function of food gut retention time, time spent feeding, time spent in flight, and the amount of fecal material produced by a goose over a specific time period. Bedard and Gauthier (1989) determined that a snow goose feeding on small grains deposits an average of 9.5 g of fecal material per hour. Based on gut retention time for small grains, a goose begins to deposit fecal material 3.1 hrs after starting to eat and continues for the remainder of the 1.65 hrs on the feeding grounds (4.75 hrs feeding time in the morning, minus 3.1 hrs gut retention time = 1.65 hrs). Therefore, a goose feeding on small grains deposits an average of 9.5 g/hr of fecal material (dw), of which 15.7 g of excreta is deposited on the feeding grounds (9.5 g/hr fecal material x 1.65 hrs). The additional 0.25 hr flight time back to the Refuge adds another 2.4 g of fecal material deposited off-Refuge, for a total of 18.1 g of fecal material/goose deposited off-Refuge in the morning. The resultant amount deposited on the Refuge from the morning feeding is 11.6 g/goose (29.7 g total excreta produced – 18.1 g deposited off-Refuge). Since gut retention time exceeds the 2.1 hrs spent feeding, plus the flight time back to the Refuge in the evening, all 13.3 g of produced fecal material is deposited on the Refuge during the evening hours. Thus, a total 24.9 g of feces is loaded/day/bird to the Refuge.

Nutrient Content of Excrement - Twenty-four composite samples of fecal material were collected from snow goose feeding grounds (Fig 10). Mean nutrient content of fecal material excreted by geese feeding on small grains was 60 mg/g total (N) and 9.1 mg/g total (P).

Total amount of nutrients excreted by a goose per day is 2.6 g N (43 g fecal material per day x 60 mg/g N = 2.6 g) and 0.4 g P. Fifty-eight percent (24.9 g) of the fecal material excreted per day is loaded to the Refuge, thus nutrient loading to the Refuge from a single goose is 1.5 g N and 0.2 g P per day.

Nutrient Loading - The total nutrient loading to the Refuge from fall migrating geese is calculated by multiplying the number of geese per day using the Refuge during fall migration with the daily amount of nutrients excreted from a goose. Linear interpolation of weekly population estimates in Table 8 was used to calculate daily populations. The total nutrient contribution to the Refuge from snow geese in 1999 is estimated to be 1,959.00 Kg N and 261.2 Kg P, while in 2000 the estimate is 4,413 Kg N and 588.4 Kg P. The mean yearly contribution of N and P from snow geese using the Refuge during fall migration (1992-2006) is 3,712.81 Kg and 495.04 Kg, respectively. The maximum amount of nutrients estimated to have been loaded by geese to the Refuge from 1992 through 2006 occurred in 1994 (10,215 Kg N and 1,362 Kg P).

Main Stem and Tributary Water Sampling

Flows - 1999 was a flood year in the Souris River Basin (Fig 11); inflow discharge (acre-feet) to the Refuge was 460% of the long-term mean (Harkness et al. 2000). Conversely, discharges in 2000 were only 60% of the long-term mean (Fig 11) (Harkness et al. 2001). In both years, the Souris River was the largest contributing inflow. Stone and Cut Bank Creeks were the least contributing in 1999 and 2000. Discharges (acre feet) downstream of the Refuge in the Souris River exhibited the same discharge patterns, i.e. very high flows in 1999, and much lower in 2000 (Fig 12).

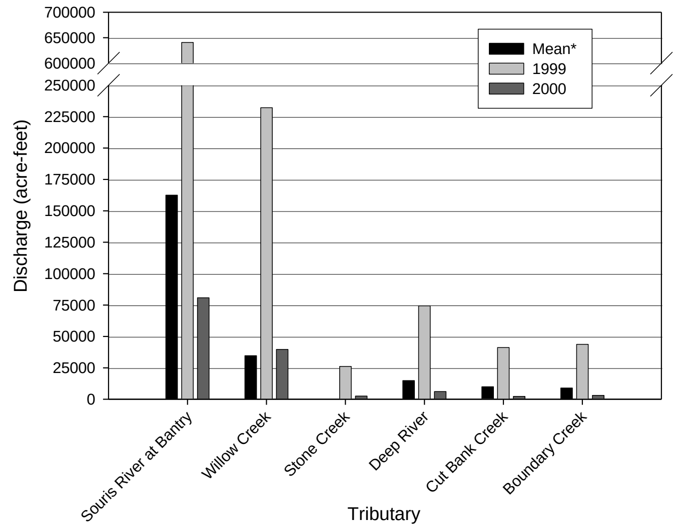


Figure 11. Gaged inflow discharge (acre-feet) into J. Clark Salyer NWR, North Dakota during 1999 and 2000, compared to long-term means.
* Long-term means from Harkness et al. (2001 & 2002); Souris River n = 63 water years, Willow Creek n = 44, Deep River n = 22, Cut Bank Creek n = 5, and Boundary Creek n = 23.

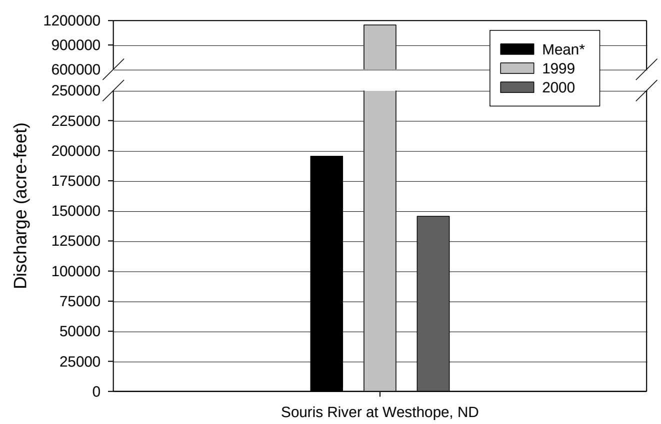


Figure 12. Gaged discharge (acre-feet) from J. Clark Salyer NWR, North Dakota measured in the Souris River at Westhope, ND during 1999 and 2000, compared to long-term mean discharge.
* Long-term mean from Harkness et al. (2000 & 2001); n = 71 water years.

Flows, measured in cubic feet/second, in 1999 exhibited typical hydrographs for northern prairie streams: spring rise associated with snow melt followed by a decline through fall with isolated flow peaks from precipitation events during the growing season (Fig 13).

Hydrographs for 2000 were atypical, with little to no spring rise and peaks from precipitation events exceeding the spring rise.

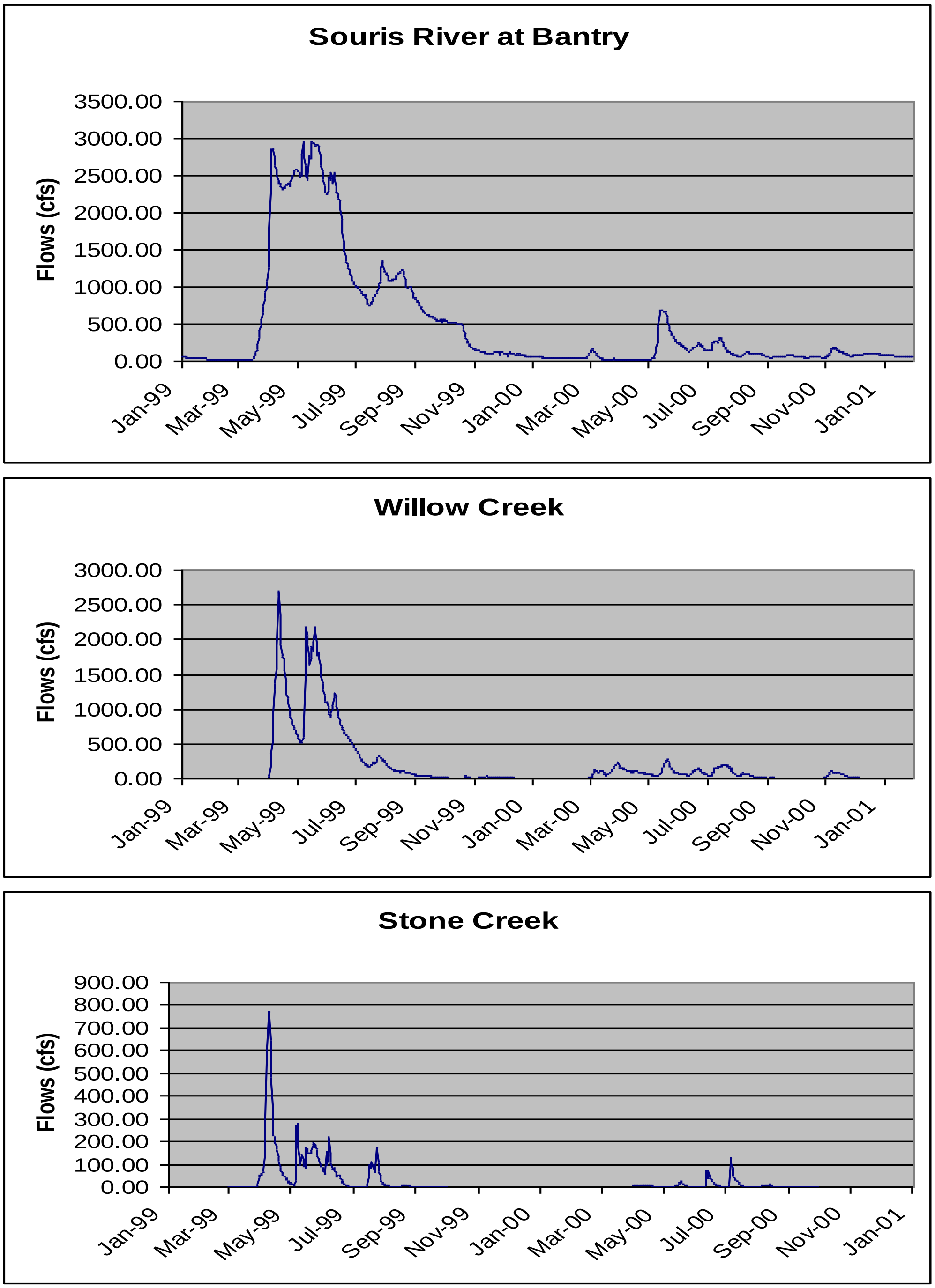
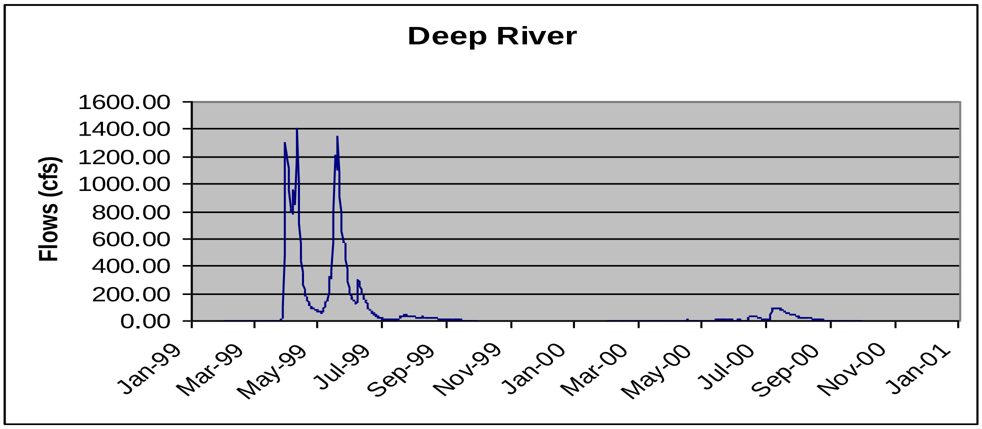
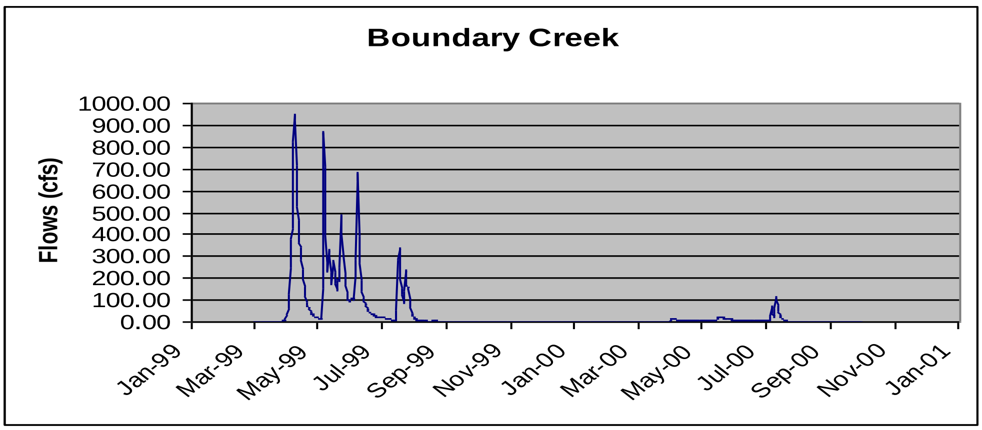


Figure 13. Daily gaged inflows to J. Clark Salyer NWR, North Dakota, 1999-2000.





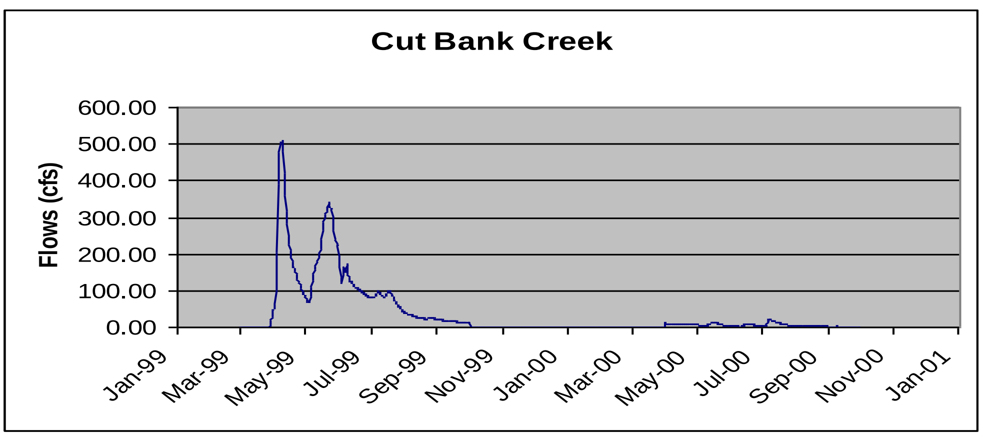


Figure 13. Cont…

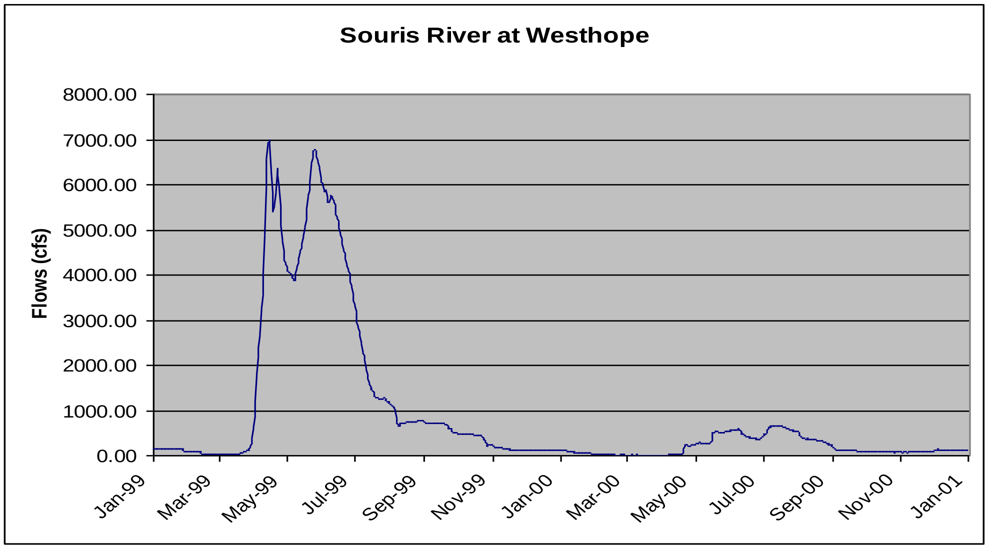


Figure 13. Cont…

Water Quality Parameters - Water sampling on inflows began in April of both years and ended in November. Exceptions to this were Stone and Cut Bank Creeks in 2000, when sampling ceased at the end of June due to no flows. Analyzed raw data for inflow samples is provided in Appendix A. This data is also available in Harkness et al. 2001 and 2002.

For any given water quality parameter, measured concentrations generally followed the same seasonal trends between the six inflows in a given year, but differed between years (Appendix B). This difference between years is not unusual, given the great differences in flows between 1999 and 2000. Also, as expected with lower flows, concentrations tended to be higher in 2000 vs. 1999 (Tables 9 & 10).

Stone Creek had the highest yearly mean total N concentrations in both 1999 and 2000 (1.86 mg/L and 2.25 mg/L, respectively) for inflows. Stone Creek also had the highest single concentration of total N for inflows in both years (3.89 mg/L and 2.53mg/L, respectively) (Tables 9 & 10). Yearly mean concentration of total N downstream of the Refuge, measured in the Souris River at Coulter, MB, was higher than any inflow, except for Stone Creek in 1999 and higher than all inflows in 2000 (Tables 9 & 10).

Organic nitrogen was the main component of total nitrogen for all inflows in both years (Tables 9 & 10). Organic nitrogen averaged 86% and 97% of total N in 1999 and 2000, respectively. This is significant, since inorganic N (ammonia + nitrate/nitrite) is the component of total N that is most readily available for immediate uptake by organisms.

Table 9. Average (min-max) concentrations or measurements of water quality parameters analyzed in water samples collected from inflow to, and downstream of J. Clark Salyer NWR, North Dakota, April – October, 1999.

	Inflow						**Downstream**
Water Quality Parameter [Transboundary Objective]	**Souris River at Bantry (n = 11)**	**Willow Creek (n = 10)**	**Stone Creek (n = 10)**	**Deep River (n = 11)**	**Cut Bank Creek (n = 10)**	**Boundary Creek (n = 10)**	**Souris River at Coulter, MB (n = 6)**
Flow (cfs)	**1568**[a] (492) (2,630)	744 (9) (2,340)	158 (1) (771)	307 (3) (1,300)	159 (15) (484)	297 (1) (804)	565 (129) (1,469)
NH_3 (mg/L)	0.03 (<0.01) (0.13)	0.03 (<0.01) (0.11)	**0.06** (<0.01) (0.31)	0.04 (<0.01) (0.28)	* (<0.01) (0.22)	0.04 (<0.01) (0.19)	0.002 (0.001) (0.01)
NO_{2+3} (mg/L) [1.0 mg/L]	0.08 (<0.02) (0.31)	0.17 (<0.02) (0.88)	**0.57** (<0.02) (3.00)	* (<0.02) (0.54)	0.10 (<0.02) (0.58)	0.05 (<0.02) (2.24)	0.03 (0.01) (0.14)
Nitrogen (Total Kjeldahl) (mg/L)	0.95 (1.18) (0.81)	1.61 (2.38) (0.95)	1.29 (1.97) (0.35)	1.58 (2.17) (0.95)	1.26 (1.74) (0.71)	1.35 (2.18) (0.48)	**1.82** (2.45) (1.52)
Total N (mg/L)	1.03 (0.90) (1.20)	1.79 (1.22) (2.61)	**1.86** (1.14) (3.89)	1.65 (0.97) (2.19)	1.36 (0.79) (1.79)	1.82 (1.27) (3.22)	1.85 (1.53) (2.58)
Total P (mg/L) [0.10 mg/L]	0.22[b] (0.10) (0.30)	0.19 (0.05) (0.30)	**0.35** (0.11) (0.56)	0.20 (0.04) (0.29)	0.19 (0.08) (0.34)	0.31 (0.23) (0.54)	0.32 (0.09) (0.67)
Dissolved P (mg/L)	0.16 (0.06) (0.25)	0.16 (0.04) (0.27)	**0.33** (0.07) (0.57)	0.17 (0.03) (0.26)	0.15 (0.07) (0.34)	0.28 (0.19) (0.49)	0.16 (0.04) (0.39)
Total Suspended Solids (mg/l) [10 mg/L]	**115.27** (8) (746)	77.10 (3) (399)	49.22 (7) (149)	20.64 (4) (92)	26.70 (2) (167)	28.70 (7) (72)	N/A

Cont…

Table 9. Cont…

Water Quality Parameter [Transboundary Objective]	Inflow						Downstream
	Souris River at Bantry (n = 11)	**Willow Creek (n = 10)**	**Stone Creek (n = 10)**	**Deep River (n = 11)**	**Cut Bank Creek (n = 10)**	**Boundary Creek (n = 10)**	**Souris River at Coulter, MB (n = 6)**
Dissolved Oxygen (mg/l) [≤5.0 mg/L]	8.47	9.41	8.40	10.35	7.81	10.52	9.57
	(4.40)	(4.00)	(5.80)	(6.40)	(1.60)	(5.20)	(3.70)
	(11.80)	(14.60)	(11.80)	(19.00)	(10.70)	(18.30)	(14.27)
Total Diss. Solids (mg/L) [1000 mg/L]	543.18	723.50	573.80	510.91	547.30	715.80	**881.83**
	(344)	(284)	(172)	(143)	(263)	(159)	(644)
	(633)	(1410)	(11200	(648)	(765)	(1640)	(1465)
SO_4 (mg/L) [450 mg/L]	179.91	245.58	232.85	120.85	184.63	**304.10**	259.00
	(114)	(98)	(40)	(33)	(89)	(32)	(184)
	(207)	(520)	(491)	(173)	(257)	(794)	(479)
Na (mg/L) [100 mg/L]	89.76	$\boxed{105.50}$	77.10	43.95	71.95	$\boxed{110.78}$	$\boxed{\mathbf{146.33}}$
	(46.30)	(40.10)	(14.50)	(8.30)	(30.90)	(12.60)	(110.00)
	(120.00)	(241.00)	(166.00)	(61.70)	(104.00)	(295.00)	(258.00)
Conductivity (umhos/cm)	849.55	1101.20	870.20	841.45	860.50	1039.20	**1198.33**
	(559)	(463)	(287)	(273)	(444)	(268)	(814)
	(977)	(2060)	(1610)	(1060)	(1200)	(2230)	(2390)
Fe (mg/L) [0.3 mg/L]	$\boxed{1.06}$	$\boxed{0.40}$	$\boxed{0.86}$	$\boxed{0.37}$	$\boxed{0.65}$	$\boxed{\mathbf{1.17}}$	$\boxed{0.58}$
	(0.19)	(0.02)	(0.04)	(0.07)	(0.01)	(0.06)	(0.14)
	(1.75)	(0.69)	(2.49)	(1.74)	(4.66)	(2.62)	(1.75)
Fecal Coliform (#/100ml) [200/100 ml]	29.82	75.60	94.10	$\boxed{201.50}$	35.44	$\boxed{\mathbf{203.90}}$	25.00
	(1)	(2)	(14)	(7)	(0)	(5)	(10)
	(90)	(420)	(257)	(1150)	(228)	(940)	(70)

Cont…

Table 9. Cont…

Water Quality Parameter [Transboundary Objective]	Inflow						Downstream
	Souris River at Bantry (n = 11)	Willow Creek (n = 10)	Stone Creek (n = 10)	Deep River (n = 11)	Cut Bank Creek (n = 10)	Boundary Creek (n = 10)	Souris River at Coulter, MB (n = 6)
Chlorophyll a (ug/L)	9.55 (3) (31)	**11.40** (3) (52)	8.00 (3) (45)	5.55 (3) (17)	3.60 (3) (7)	4.90 (3) (22)	0.03 (0) (0.05)
pH [6.5 – 8.5]	7.80 (7.10) (8.26)	7.88 (6.78) (8.65)	7.64 (6.74) (8.59)	8.01 (6.98) (8.68)	7.57 (7.07) (8.26)	7.72 (6.84) (8.74)	8.36 (7.69) (8.93)

[a] Bold numbers indicate highest mean concentration for a particular water quality parameter.
[b] Blocked numbers indicate an exceedance of the Transboundary Water Quality Objective.
[*] No average given when greater than half of samples are below detection limit.

Table 10. Average (min - max) concentrations or measurements of water quality parameters analyzed in water samples collected from inflows to, and downstream of J. Clark Salyer NWR, North Dakota, May – November, 2000.

Water Quality Parameter [Transboundary Objective]	Inflow						Downstream
	Souris River at Bantry (n = 9)	Willow Creek (n = 9)	Stone Creek[a] (n = 6)	Deep River (n = 9)	Cut Bank Creek[a] (n = 6)	Boundary Creek (n = 6)	Souris River at Coulter, MB (n = 8)
Flow (cfs)	95.44 (25.00) (181.00)	61.27 (3.40) (125.00)	5.60 (0.49) (24.00)	9.32 (0.00) (47.00)	6.00 (1.30) (13.00)	8.82 (3.90) (23.00)	**247.67**[b] (16.98) (663.83)
NH_3 (mg/L)	* (<0.01) (0.09)	* (<0.01) (0.17)	* (<0.01) (0.10)	0.05 (<0.01) (0.15)	* (<0.01) (<0.01)	* (<0.01) (0.12)	0.01 (0.001) (0.02)
NO_{2+3} (mg/L) [1.0 mg/L]	0.10 (<0.02) (0.29)	* (<0.02) (0.26)	* (<0.02) (0.04)	0.10 (<0.02) (0.57)	* (<0.02) (<0.02)	* (<0.02) (0.03)	0.02 (0.01) (0.07)

Cont…

Table 10. Continued

Water Quality Parameter [Transboundary Objective]	Inflow						Downstream
	Souris River at Bantry (n = 9)	**Willow Creek (n = 9)**	**Stone Creek[a] (n = 6)**	**Deep River (n = 9)**	**Cut Bank Creek[a] (n = 6)**	**Boundary Creek (n = 6)**	**Souris River at Coulter, MB (n = 8)**
Nitrogen (Total Kjeldahl) (mg/L)	1.25	1.90	2.23	1.92	1.81	1.87	**2.28**
	(0.85)	(1.42)	(1.82)	(1.71)	(1.46)	(1.64)	(1.53)
	(1.82)	(2.26)	(2.49)	(2.29)	(2.06)	(2.44)	(3.69)
Total N (mg/L)	1.35	1.95	2.25	2.02	1.83	1.89	**2.30**
	(0.87	(1.44)	(1.84)	(1.76)	(1.48)	(1.66)	(1.54)
	(1.95	(2.28)	(2.53)	(2.43)	(2.08)	(2.46)	(3.76)
Total P (mg/L) [0.1 mg/L]	$\boxed{0.28}$[c]	$\boxed{0.19}$	$\boxed{0.27}$	$\boxed{0.20}$	$\boxed{0.30}$	$\boxed{0.25}$	$\boxed{\mathbf{0.57}}$
	(0.08	(0.07)	(0.09)	(0.04)	(0.13)	(0.09)	(0.18)
	(0.58	(0.33)	(0.46)	(0.61)	(0.41)	(0.47)	(1.76)
Dissolved P (mg/L)	0.21	0.13	0.22	0.15	**0.27**	0.21	0.23
	(0.02	(0.02)	(0.04)	(0.01)	(0.11)	(0.04)	(0.03)
	(0.47	(0.28)	(0.41)	(0.54)	(0.38)	(0.45)	(0.47)
Total Suspended Solids (mg/l) [10 mg/L]	$\boxed{\mathbf{98.78}}$	$\boxed{56.67}$	$\boxed{62.33}$	$\boxed{17.43}$	9.67	$\boxed{19.50}$	N/A
	(17.00)	(28.00)	(7.00)	(6.00)	(2.00)	(8.00)	
	(226.00)	(96.00)	(310.00)	(43.00)	(29.00)	(46.00)	
Dissolved Oxygen (mg/l) [$\leq$5.0 mg/L]	9.27	8.71	11.37	8.77	8.40	11.62	7.26
	(4.60)	(5.20)	(8.00)	(3.40)	(4.40)	(7.00)	(1.86)
	(13.60)	(12.10)	(21.60)	(13.50)	(10.40)	(21.00)	(13.71)
Total Dissolved Solids (mg/L) [1000 mg/L]	$\boxed{1032.89}$	$\boxed{1133.00}$	$\boxed{\mathbf{2415.00}}$	781.33	930.67	$\boxed{1553.11}$	876.01
	(731)	(928)	(1770)	(567)	(860)	(977)	(645.32)
	(1400)	(1450)	(2930)	(946)	(987)	(2240)	(1421.76)

Cont…

Table 10. Cont…

Water Quality Parameter [Transboundary Objective]	Inflow						Downstream
	Souris River at Bantry (n = 9)	**Willow Creek (n = 9)**	**Stone Creek[a] (n = 6)**	**Deep River (n = 9)**	**Cut Bank Creek[a] (n = 6)**	**Boundary Creek (n = 6)**	**Souris River at Coulter, MB (n = 8)**
SO_4 (mg/L) [450 mg/L]	380.11 (242) (547)	$\boxed{482.78}$ (365) (696)	$\boxed{\mathbf{1392.17}}$ (993) (1740)	270.57 (95) (395)	317.17 (285) (340)	743.56 (358) (1200)	370.25 (249) (594)
Na (mg/L) [100 mg/L]	$\boxed{205.00}$ (107) (317)	$\boxed{187.22}$ (127) (248)	$\boxed{\mathbf{398.33}}$ (292) (496)	71.76 (60) (95)	$\boxed{126.33}$ (111) (137)	$\boxed{281.11}$ (184) (403)	$\boxed{203.25}$ (10) (295)
Conductivity (umhos/cm)	1536.67 (1110) (2080)	1625.56 (1360) (1980)	**3005.00** (2260) (3650)	1214.78 (993) (1450)	1391.67 (1260) (1460)	2091.11 (1460) (2830)	1620.00 (918) (2880)
Fe (mg/L) [0.3 mg/L]	$\boxed{\mathbf{1.40}}$ (0.51) (2.54)	$\boxed{0.88}$ (0.64) (1.55)	0.24 (0.08) (0.39)	0.27 (0.14) (0.77)	0.04 (0.02) (0.07)	$\boxed{0.61}$ (0.19) (2.16)	$\boxed{0.52}$ (0.20) (0.83)
Fecal Coliform (#/100 ml) [200/100 ml]	72.67 (5) (230)	$\boxed{200.44}$ (5) (960)	158.75 (39) (413)	61.44 (1) (160)	18.17 (0) (34)	$\boxed{\mathbf{349.67}}$ (7) (1240)	30.00 (10) (170)
Chlorophyll a (ug/L)	16.44 (3) (36)	14.78 (3) (44)	5.67 (3) (16)	17.11 (3) (51)	3.67 (3) (7)	**21.78** (3) (92)	0.02 (0) (0.1)
pH [6.5 – 8.5]	8.22 (8.00) (8.39)	8.35 (7.92) (8.53)	8.29 (8.17) (8.45)	8.33 (8.05) (8.61)	8.43 (8.18) (8.65)	$\boxed{8.56}$ (8.36) (8.96)	8.44 (7.76) (8.87)

[a] Stone and Cut Bank Creeks were only sampled through June due to absence of flows thereafter.
[b] Bold numbers indicate highest mean concentration for a particular water quality parameter.
[c] Blocked numbers indicate an exceedance of the Transboundary Water Quality Objective.
[*] No average given when greater than half of samples are below detection limit.

Yearly mean total P concentrations in all flows exceeded the Transboundary Water Quality Objective of 0.10 mg/L in both years (Tables 9 & 10). Total P was comprised mostly of dissolved P. Dissolved P is the component of total P that is most readily available for uptake by organisms. Eighty-four percent of the inflow concentrations of total P in 1999 was the dissolved compound, and in 2000 dissolved P comprised 79% of the total P (Tables 9 & 10). In both years, the percentage of total P that was dissolved in downstream flows, measured in the Souris River at Coulter, was 50% and 40%, respectively.

Yearly mean concentrations of total suspended solids (TDS) in both years within inflows exceeded the Transboundary Objective of 10 mg/L (Tables 9 & 10). Only Cut Bank Creek in 2000 had a mean less than the Transboundary Objective (9.67 mg/l). The Souris River at Bantry had the highest yearly mean concentrations during both years. TDS concentrations were unavailable downstream of the Refuge at Coulter. Yearly mean concentrations of DO did not fall below the Transboundary Objective of 5.0 mg/L (Tables 9 & 10). There were, however, individual instances where minimum DO levels were measured below the 5.0 mg/L (Tables 9 & 10).

SO_4, Na, conductivity, and TDS all had virtually identical seasonal trends among inflows during both years (Appendix B). Boundary and Willow Creeks consistently had some of the highest yearly mean concentrations in 1999 for all four parameters (Table 9). These two tributaries also had some of the highest yearly mean concentrations in 2000 (Table 10). Exceedences of the Transboundary Objectives for these four parameters occurred more often in the low-flow year of 2000 than in the flood year 1999 (Tables 9 & 10).

Boundary Creek's yearly mean concentrations of fecal coliforms exceeded the Transboundary Objective in both years (Tables 9 & 10). Boundary Creek and Deep River had the highest concentrations in 1999, and Boundary and Willow Creeks the highest in 2000 (Tables 9 & 10). Fecal concentrations measured downstream of the Refuge were less than concentrations in the inflows during both years. At no time during 1999 or 2000 did concentrations of fecal coliforms exceed 200 colonies/100 ml downstream of the Refuge at Coulter.

Yearly mean iron concentrations exceeded Transboundary Objectives (0.3 mg/L) at all locations during 1999 (Table 9). The highest inflow means were recorded in Boundary Creek and Souris River. In 2000, yearly mean concentrations exceeded Transboundary Objectives in only three inflow locations and downstream of the Refuge at Coulter (Table 10). Again in 2000, the Souris River had the highest inflow concentrations.

<u>Nutrient And Ion Loading From Inflow</u> - During 1999, 54% to 86% of all parameters loaded to the Refuge were brought in by the Souris River and Willow Creek combined (Table 11), and in 2000 these two inflows combined to provide 81% to 98% of all loaded parameters. Cut Bank Creek in both years contributed the least loading to the Refuge. Depending upon parameter, loads to the Refuge were anywhere from 2.4 to 12.3 times greater in 1999 than in 2000 (Table 11). Loads in the Souris River downstream of the Refuge at Coulter are provided in Table 12.

Table 11. Yearly loads (kg x 1000) of water quality parameters (% in parenthesis) contributed via inflows to J. Clark Salyer NWR, North Dakota, 1999-2000.

Inflow (1999)	NH_3 kg/yr	NO_2+NO_3 kg/yr	Total Kjeldahl N kg/yr	Total N kg/yr	Total P kg/yr	Dissolved P kg/yr	Total Dissolved Solids kg/yr	Total Suspended Solids kg/yr	SO_4 kg/yr	Na kg/yr	Total Flow hm3
Souris River at Bantry	**27.6**[a] (50)	64.4 (25)	**747.5** (55)	**812.0** (51)	**160.7** (60)	**122.7** (56)	**417,391.3** (64)	**50,707.8** (73)	**142,171.9** (58)	**67,765.4** (66)	790
Willow Creek	9.2 (17)	**76.2** (29)	359.3 (26)	435.5 (27)	52.4 (20)	49.1 (22)	140,334.4 (21)	9,155.6 (13)	64,385.3 (26)	19,264.1 (19)	286
Cut Bank Creek	1.4 (3)	5.5 (2)	63.2 (5)	69.3 (4)	8.5 (3)	6.3 (3)	23,063.1 (4)	1,506.0 (2)	8,866.1 (4)	4,104.0 (4)	51
Deep River	11.7 (21)	18.9 (7)	103.5 (8)	129.9 (8)	19.5 (7)	17.8 (8)	27,044.6 (4)	4,090.8 (6)	11,641.2 (5)	3,304.8 (3)	92
Stone Creek	3.3 (6)	49.0 (19)	24.2 (2)	73.2 (5)	10.0 (4)	9.7 (4)	15,395.0 (2)	2,320.8 (3)	7,164.1 (3)	2,015.3 (2)	32
Boundary Creek	2.0 (4)	45.6 (18)	63.1 (5)	86.2 (5)	15.4 (6)	14.9 (7)	31,850.1 (5)	1,708.2 (2)	9,698.8 (4)	5,974.3 (6)	54
Total 1999 Load	55.2	259.7	1,360.7	1,606.0	266.5	220.4	655,078.5	69,489.1	243,927.5	102,427.9	1,305

Cont…

Table 11. Cont…

Inflow (2000)	NH_3 kg/yr	NO_2+NO_3 kg/yr	Total Kjeldahl N kg/yr	Total N kg/yr	Total P kg/yr	Dissolved P kg/yr	Total Dissolved Solids kg/yr	Total Suspended Solids kg/yr	SO_4 kg/yr	Na kg/yr	Total Flow hm3
Souris River at Bantry	2.3 (35)	**12.9** (66)	**124.0** (50)	**136.9** (52)	**30.0** (66)	**21.8** (62)	**95,214.6** (60)	**15,735.6** (77)	**35,498.0** (54)	**18,914.7** (64)	100
Willow Creek	**3.6** (53)	3.0 (15)	94.7 (38)	97.6 (37)	10.9 (24)	9.0 (26)	45,896.1 (29)	4,251.0 (21)	21,921.1 (33)	6,153.7 (21)	49
Cut Bank Creek	0.05 (1)	0.1 (0)	4.8 (2)	4.9 (2)	0.6 (1)	0.6 (2)	2,330.1 (1)	15.8 (0)	823.3 (1)	601.6 (2)	3
Deep River	0.5 (7)	0.8 (4)	11.3 (5)	12.5 (5)	2.1 (5)	1.8 (5)	3,646.9 (2)	227.2 (1)	3,005.6 (5)	993.8 (3)	8
Stone Creek	0.2 (3)	2.7 (14)	3.9 (2)	6.6 (2)	0.8 (2)	0.7 (2)	3,937.8 (2)	162.6 (1)	2,287.9 (3)	624.8 (2)	3
Boundary Creek	0.1 (1)	0.1 (0)	8.1 (3)	7.0 (3)	1.0 (2)	0.9 (3)	7,317.4 (5)	69.0 (0)	3,709.4 (4)	2,261.4 (8)	5
Total 2000 Load	6.7	19.5	246.8	265.5	45.4	35.0	158,343.0	20,461.2	66,245.3	29,550.0	167

[a] Bolded numbers indicate greatest load for a particular water quality parameter.

Table 12. Yearly loads (kg x 1000) of water quality parameters calculated for the Souris River at Coulter, MB, approximately six miles downstream from J. Clark Salyer NWR, North Dakota, 1999-2000.

Year	NH_3 kg/yr	NO_2+NO_3 KG/yr	Total Kjeldahl N kg/yr	Total N kg/yr	Total P kg/yr	Dissolved P kg/yr	Total Dissolved Solids kg/yr	Total Suspended Solids kg/yr	SO_4 kg/yr	Na kg/yr	Total Flow hm3
1999	7.8	27.8	2,611.9	2,639.7	664.3	371.9	1,121,832.0	N/A	373,052.6	205,092.1	1,413
2000	1.0	3.5	331.6	335.1	84.3	47.2	142,408.9	N/A	47,356.4	26,035.0	179

Metal Concentrations - Water samples were analyzed for metal concentrations. Results of these analyses are not discussed in this report. Raw metal data from sampling is available in Harkness et al. (2000 and 2001).

Refuge Pool Water Quality

Mean concentrations of total P and Fe exceeded Transboundary Objectives in all five pools both years (Tables 13 & 14). The Transboundary Objectives for Na was also exceeded in all pools in 2000. Total N within the Refuge pools was comprised of 91% organic N in 1999, and virtually all total N (98%) in 2000 was organic (Tables 13 & 14). Total P in 1999 was 85% comprised of dissolved P, while in 2000 dissolved P made up 77% of total P in Refuge pools (Tables 13 & 14).

Table 13. Average (min- max) concentrations or measurements of water quality parameters analyzed in water samples collected from individual refuge pools on J. Clark Salyer NWR, North Dakota, April - October, 1999

Water Quality Parameter [Transboundary Objective]	Pool #				
	320 (n = 11)	**326 (n = 8)**	**332 (n = 11)**	**341 (n = 11)**	**357 (n = 11)**
NH_3 (mg/L)	0.04 (<0.01) (0.25)	0.05 (<0.01) (0.19)	0.04 (<0.01) (0.19)	0.04 (<0.01) (0.25)	**0.07**[a] (<0.01) (0.44)
NO2+NO3 (mg/L) [1.0 mg/L]	0.08 (<0.02) (0.43)	0.08 (<0.02) (0.33)	0.09 (<0.02) (0.45)	0.02 (<0.02) (1.15)	*0.15* *(<0.02)* *(0.66)*

Table 13. Cont…..

Table 13 Continued…

Water Quality Parameter [Transboundary Objective]	Pool #				
	320 (n = 11)	**326 (n = 8)**	**332 (n = 11)**	**341 (n = 11)**	**357 (n = 11)**
Nitrogen (Total Kjeldahl) (mg/L)	1.19	**1.43**	1.30	1.29	1.25
	0.94)	(0.98)	(0.95)	(1.00)	(0.84)
	(1.63)	(3.00)	(1.69)	(1.65)	(1.70)
Total N (mg/L)	1.27	**1.52**	1.39	1.41	1.39
	(0.99)	1.07)	(1.11)	(1.07)	(1.06)
	(1.67)	(3.02)	(1.73)	(1.92)	(1.87)
Total P (mg/L) [0.10 mg/L]	$\boxed{0.23^{b}}$	$\boxed{0.23}$	$\boxed{0.22}$	$\boxed{\mathbf{0.31}}$	$\boxed{0.25}$
	(0.16)	(0.14)	(0.12)	(0.11)	(0.10)
	(0.37)	(0.36)	(0.33)	(1.00)	(0.41)
Dissolved P (mg/L)	0.20	0.21	0.19	0.21	**0.22**
	0.11)	(0.10)	(0.08)	(0.07)	(0.04)
	(0.32)	(0.34)	(0.32)	(0.38)	(0.37)
Total Dissolved Solids (mg/L) [1000 mg/L]	548.09	**575.00**	564.58	548.68	555.36
	(262.00)	(352.00)	(247.67)	(236.50)	(234.00)
	(652.00)	(640.00)	(726.33)	(664.50)	(668.67)
Dissolved Oxygen (mg/L) [≤5.0 mg/L]	8.40	7.64	8.06	8.21	8.78
	(2.70)	(3.20)	(3.93)	(2.85)	(2.90)
	(17.80)	(12.20)	(11.87)	(13.85)	(15.40)
Fe (mg/L) [0.3 mg/L]	$\boxed{\mathbf{0.70}}$	$\boxed{0.41}$	$\boxed{0.41}$	$\boxed{0.46}$	$\boxed{0.56}$
	(0.06)	(0.16)	(0.06)	(0.04)	(0.08)
	(1.76)	(0.93)	(0.94)	(0.87)	(1.97)
Fecal Coliforms (#/100 ml) [200/100 mL]	**56.60**	40.13	30.45	29.59	34.33
	(0.00)	(8.00)	(4.67)	(2.50)	(3.67)
	(200.00)	(75.00)	(94.33	(126.00)	(137.00)

Table 13. Cont…

Table 13. Cont…

Water Quality Parameter [Transboundary Objective]	Pool #				
	320 n = 11	**326 n = 8**	**332 n = 11**	**341 n = 11**	**`357 n = 11**
Secchi Depth (m)	N/A	N/A	N/A	N/A	N/A
	N/A N/A	N/A N/A	N/A N/A	N/A N/A	N/A N/A
Chlorophyll a (ug/L)	**8.59**	6.94	5.73	6.80	7.42
	(1.50) (21.00)	(1.50) (18.00)	(1.50) (21.33)	(1.50) (25.50)	(1.50) (34.00)
pH [6.5 – 8.5]	7.79	7.89	7.85	7.83	7.99
	(7.02) (8.46)	(6.89) (8.34)	(6.97) (8.44)	(6.85) (8.44)	(6.97) (8.58)
Conductivity (umhos/cm)	864.00	**912.00**	892.06	865.45	873.52
	(452.00) (1010.00)	(569.00) (1020.00)	(417.00) (1143.67)	(395.00) (1050.00)	(398.33) (1043.33)
SO_4 (mg/L) [450 mg/L]	178.59	**182.63**	180.71	175.04	175.93
	(83.50) (220.00)	(102.00) (212.00)	(69.27) (268.33)	(66.15) (215.50)	(63.17) (227.67)
Na (mg/L) [100 mg/L]	88.90	**96.36**	80.57	87.49	87.70
	(33.00) (114.00)	(51.30) (112.00)	(27.47) (107.97)	(26.55) (116.50)	(25.83) (116.00)

[a] Bold numbers indicate highest mean concentration for a particular water quality parameter.
[b] Blocked numbers indicate an exceedance of Transboundary Water Quality Objectives

Table 14. Average (Min - max) concentrations or measurements of water quality parameters analyzed in water samples collected from individual refuge pools on J. Clark Salyer NWR, North Dakota, May - November, 2000.

Water Quality Parameter [Transboundary Objective]	Pool #				
	320 n = 8	**326 n = 8**	**332 n = 8**	**341 n = 8**	**357 n = 8**
NH_3 (mg/L)	*	0.05	**0.06**[a]	**0.06**	0.04
	(<0.01) (0.16)	(<0.01) (0.29)	(<0.01) (0.28)	(<0.01) (0.30)	(<0.01) (0.17)
NO_2+NO_3 (mg/L) [1.0 mg/L]	0.04	*	0.03	0.03	**0.09**
	(<0.02) (0.07)	(<0.02) (0.05	(<0.02) (0.07)	(<0.02) (0.09)	(<0.02) (0.53)
Nitrogen (Total Kjeldahl) (mg/L)	1.54	1.70	1.75	**1.79**	1.69
	1.08) (1.92	(1.36) (2.06)	(1.39) (1.98	(1.42) (2.10)	(1.09) (1.98)
Total N (mg/L)	1.58	1.73	1.78	**1.82**	1.74
	1.10) (1.99	(1.38) (2.11)	(1.41) (2.01)	(1.44) (2.15)	(1.11) (2.00)
Total P (mg/L) [0.1 mg/L]	$\boxed{0.27^{b}}$	$\boxed{0.28}$	$\boxed{0.26}$	$\boxed{0.28}$	$\boxed{\mathbf{0.30}}$
	(0.10) (0.42	(0.09) (0.46)	0.09) (0.42	(0.08) (0.45)	(0.11) (0.46)
Dissolved P (mg/L)	0.20	0.22	0.20	0.23	**0.24**
	0.04) (0.35	(0.04) (0.38)	(0.03) (0.36)	(0.04) (0.38)	(0.03) (0.42)
Total Dissolved Solids (mg/L) [1000 mg/L]	$\boxed{1015.50}$	999.75	942.79	978.38	$\boxed{\mathbf{2956.23}}$
	(839.00) (1270.00)	(825.00) (1200.00)	794.67) (1171.33)	(798.50) (1115.00)	958.67) (1120.00)
Dissolved Oxygen (mg/L) [<u><</u>5.0 mg/L]	8.68	9.15	8.50	9.18	9.35
	(4.00) (12.60)	(5.70) (12.00)	(5.07) (11.90)	(5.45) (12.70)	(5.87) (12.70)

Table 14 Cont…

Table 14. Cont…

Water Quality Parameter [Transboundary Objective]	Pool # 320 n = 8	326 n = 8	332 n = 8	341 n = 8	357 n = 8
Fe (mg/L) [0.3 mg/L]	$\boxed{\mathbf{1.07}}$	$\boxed{0.85}$	$\boxed{0.52}$	$\boxed{0.45}$	$\boxed{0.64}$
	(0.37)	(0.28)	(0.20)	(0.09)	(0.17)
	(1.59)	(2.18)	(1.01)	(1.34)	(1.89)
Fecal Coliforms (#/100 ml) [200/100 ml]	100.50	42.38	24.63	**137.31**	28.21
	(3.00)	(3.00)	(4.67)	(3.00)	(5.50)
	(480.00)	(100.00)	(51.00)	(845.50)	(97.33)
Secchi Depth (m)	0.41	0.46	0.60	**0.84**	0.81
	(0.30)	(0.28)	(0.04)	(0.29)	(0.30)
	(0.58)	(0.91)	(1.06)	(1.59)	(1.60)
Chlorophyll a (ug/L)	20.06	22.56	20.31	**25.72**	20.50
	(1.50)	(1.50)	(5.67)	(1.50)	(1.50)
	(35.00)	(43.00)	(37.00)	(66.00)	(51.93)
pH [6.5 – 8.5]	8.37	8.38	8.20	8.39	8.52
	(8.17)	(8.19)	(6.26)	(8.02)	(8.22)
	(8.58)	(8.54)	(8.64)	(8.62)	(8.81)
Conductivity (umhos/cm)	1493.75	1485.00	**1505.83**	1460.63	1422.08
	(1230.00)	(1230.00)	(1196.67)	(1200.00)	(998.33)
	(1850.00	(1770.00)	(2330.00)	(1625.00)	(1585.00)
SO_4 (mg/L) [450 mg/L]	383.75	379.38	371.08	376.00	**384.85**
	(316.00)	(322.00)	(279.67)	(335.00)	(324.67)
	(540.00)	(510.00)	(616.33)	(466.50)	(469.33)
Na (mg/L) [100 mg/L]	$\boxed{\mathbf{196.25}}$	$\boxed{192.63}$	$\boxed{158.77}$	$\boxed{184.75}$	$\boxed{189.58}$
	(135.00)	(134.00)	(120.67)	(128.50)	(131.00)
	(258.00)	(243.00)	(187.33)	(238.50)	(259.33)

[a] Bold numbers indicate highest mean concentration for a particular water quality parameter.
[b] Blocked numbers indicate an exceedance of Transboundary Water Quality Objectives.
[*] No average given when greater than half of samples are below detection limit.

Concentrations of individual parameters for each pool were plotted against time (April through October) for 1999 and 2000 (Figure 14). This figure shows that for any given parameter, its respective concentrations across all five pools had similar trends in each year. In addition to similar temporal trends in a year, measured concentrations in a given month did not differ widely between the pools. For example, each month's Kjeldahl nitrogen concentrations were combined across all pools in 1999 and a geometric mean monthly concentration calculated for each respective month (April-October). The standard errors around these monthly means ranged from ±0.01 to ±0.16. Standard errors for Kjeldahl nitrogen mean monthly concentrations in 2000 ranged from ±0.03 to ±0.14. In fact, standard errors around 126 monthly means (from both years) for nine parameters ranged from ±0.003 to ±1.18. Only chlorophyll a (SE ±0.25 to ±8.61), fecal coliforms (SE ±1.08 to ±153.62), TDS (SE ±5.89 to ±32.20), conductivity (SE ±7.84 to ±16.46), SO_4 (SE ±2.71 to ±53.78), and Na (SE ±1.02 to ±14.23) had large standard errors around their means.

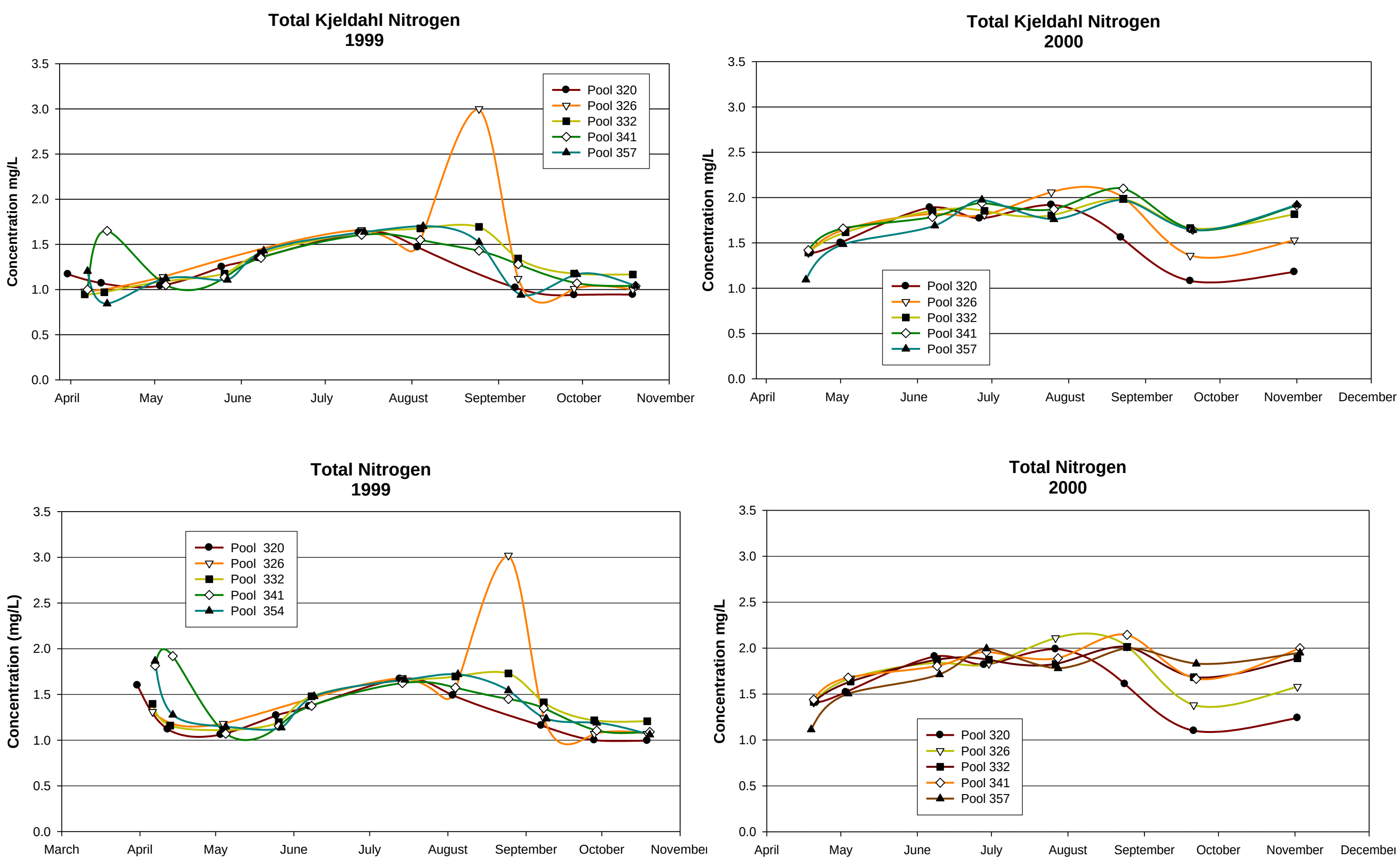
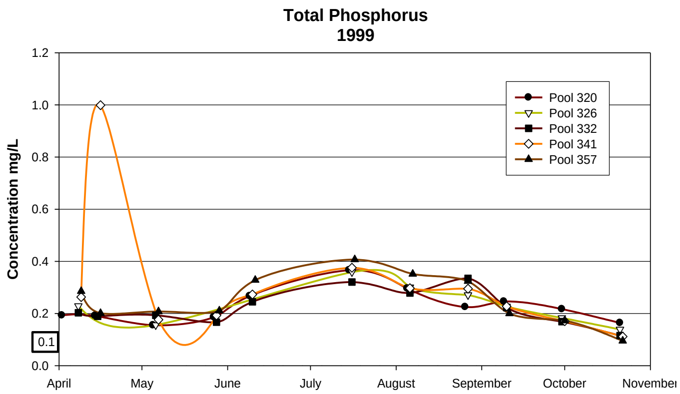
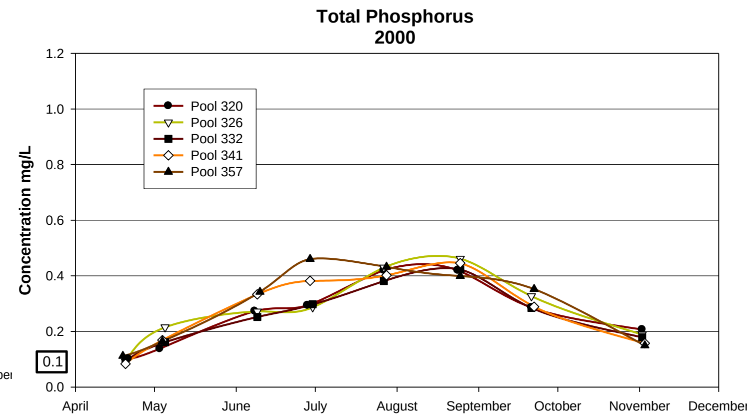
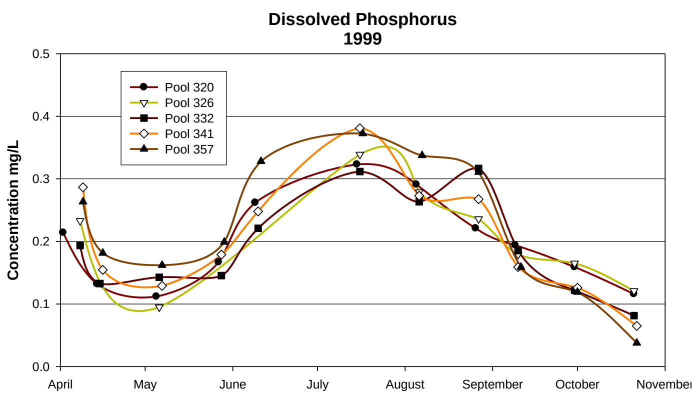
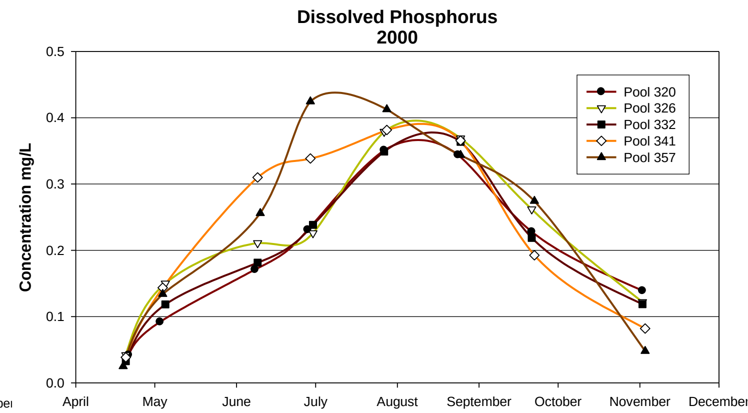


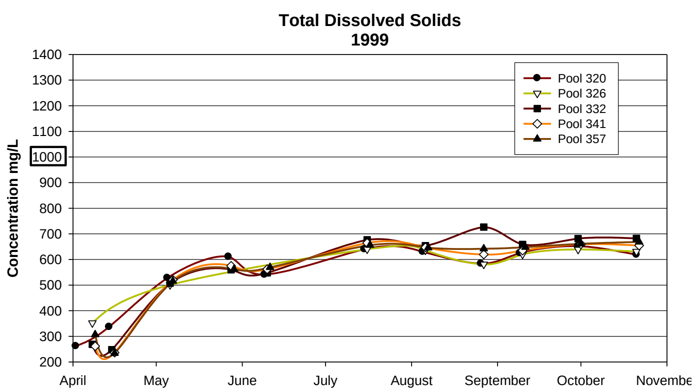
Figure 14. 1999 and 2000 seasonal trends of water quality parameters in pools on J. Clark Salyer NWR, North Dakota.











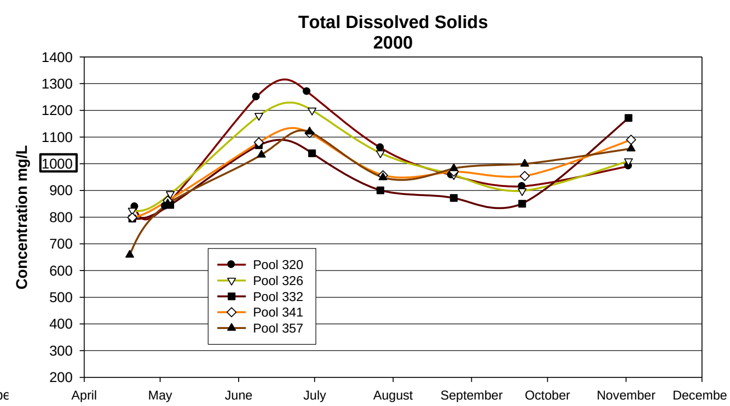


Figure 14. Cont…☐= Transboundary Water Quality Objective

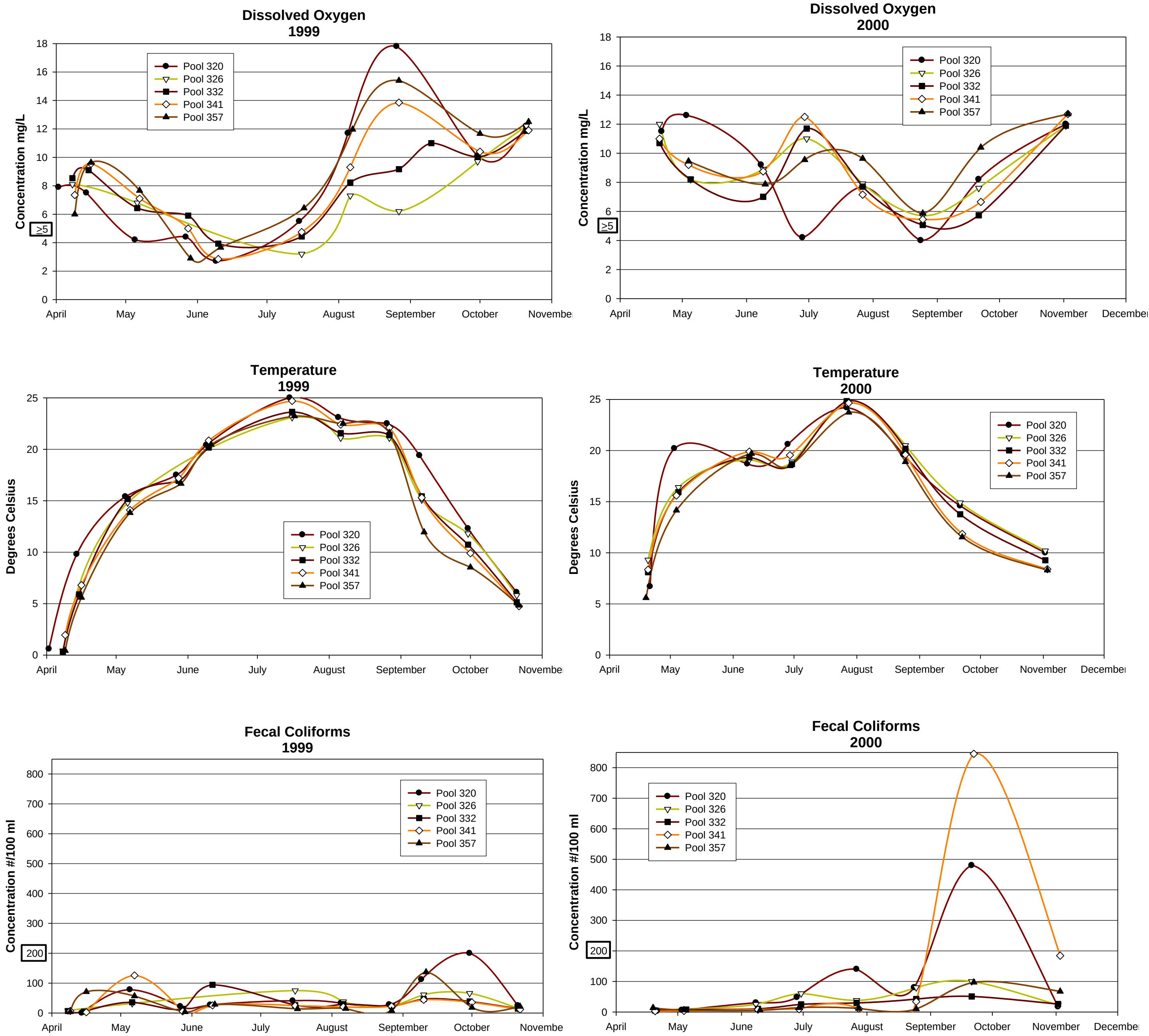


Figure 14. Cont…☐= Transboundary Water Quality Objective.

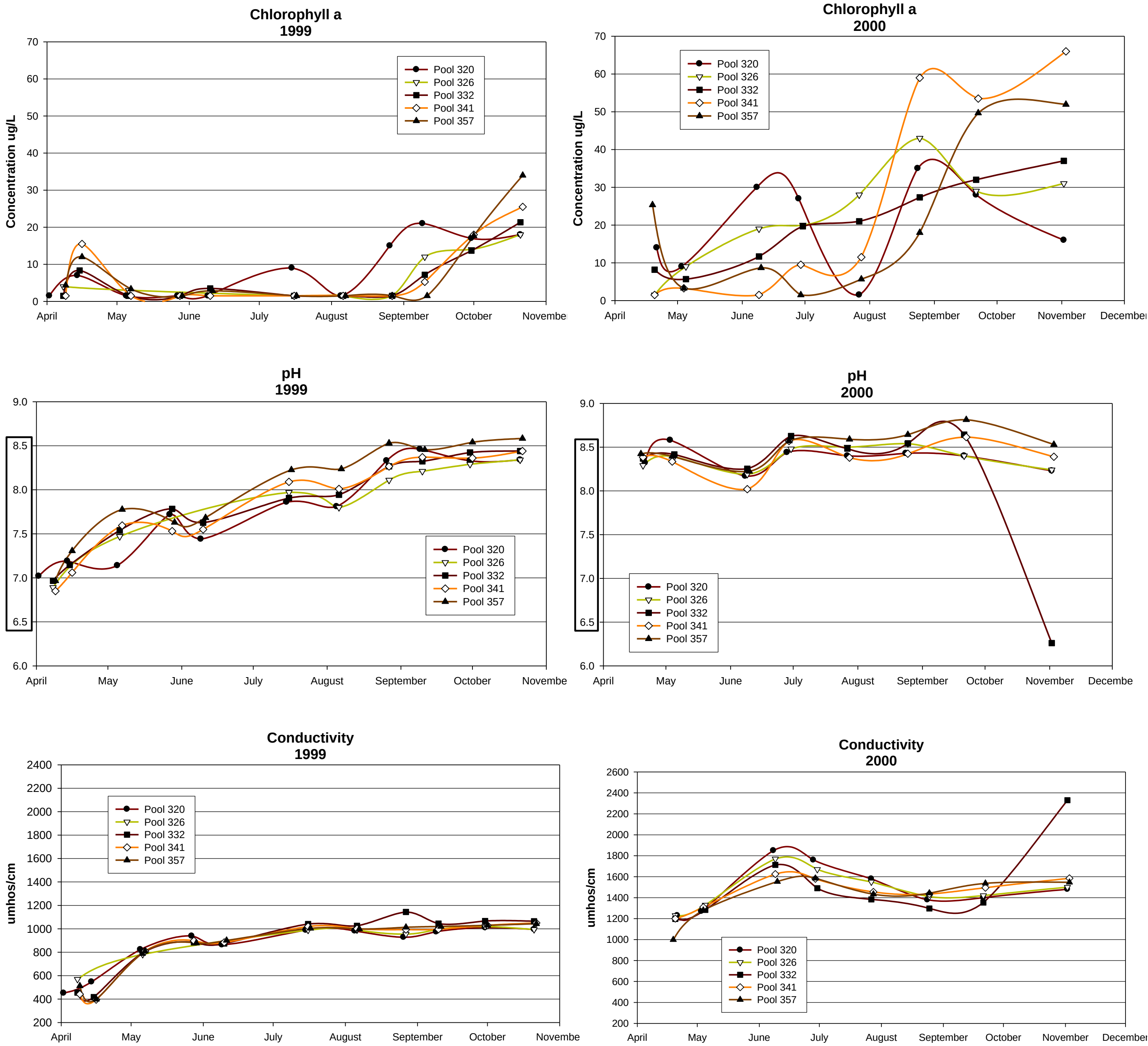


Figure 14. Cont…□= Transboundary Water Quality Objective.

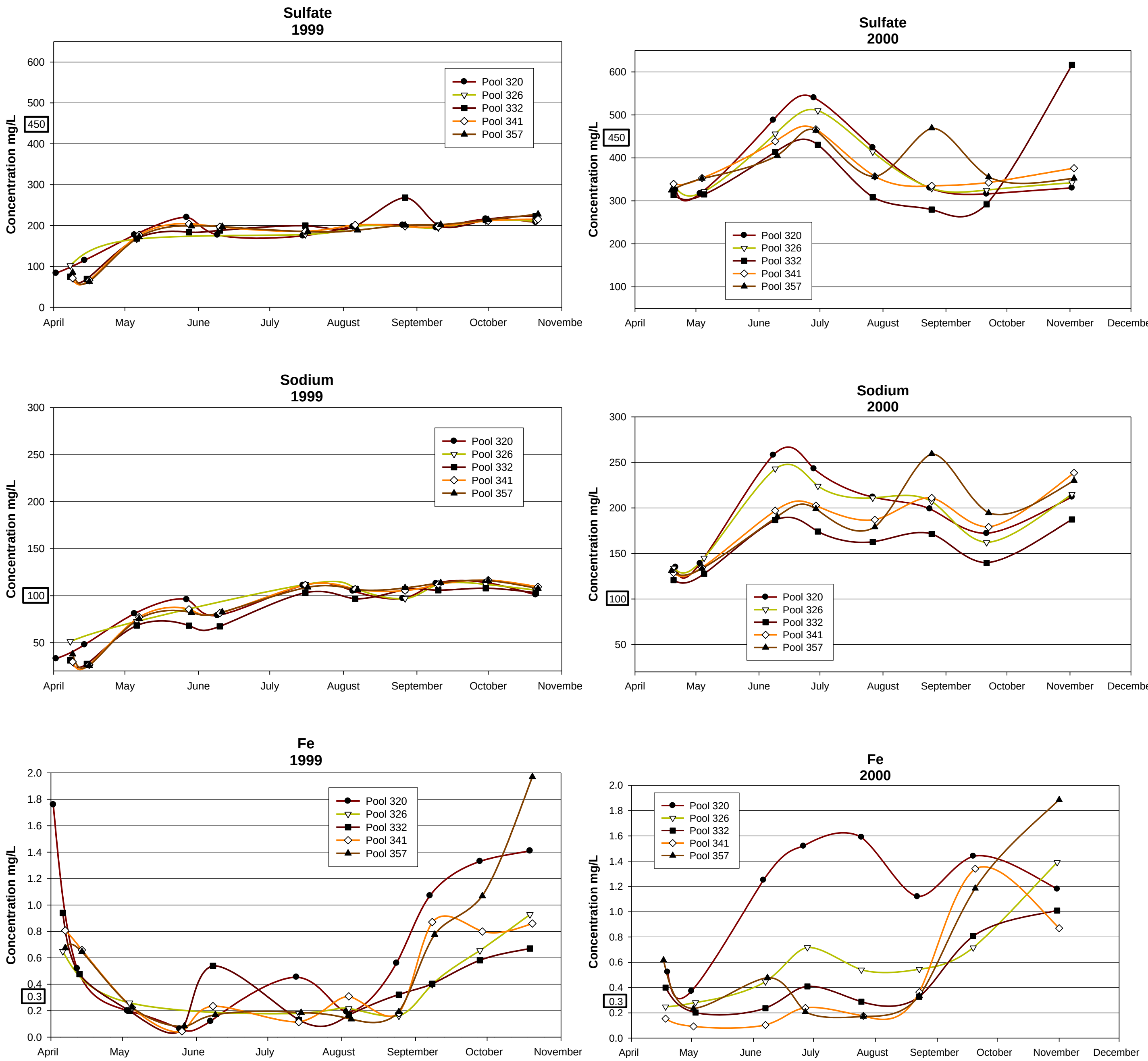


Figure 14. Cont.. $\square$ = Transboundary Water Quality Objective.

Because seasonal trends and monthly concentrations for a given parameter were similar across all pools, the concentrations for each parameter were combined to get monthly means and then plotted for each year to provide a visual representation of concentrations throughout the Refuge as a whole (Figure 15). Concentrations and physical measurements in the Refuge pools were typically higher in year 2000 than 1999.

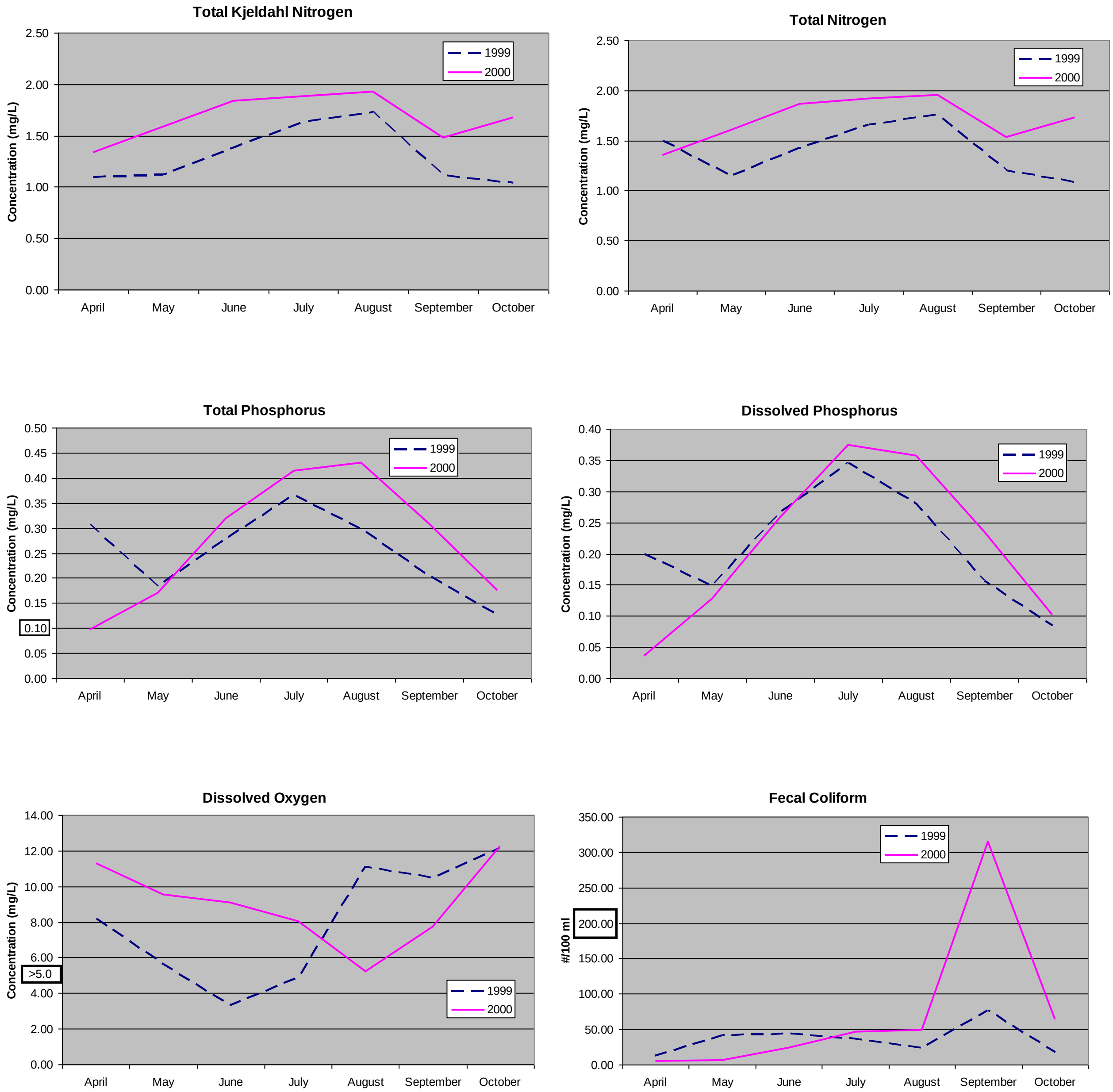


Figure 15. Average monthly concentrations of water quality parameters sampled in the five pools on J. Clark Salyer NWR, North Dakota, 1999 and 2000. $\square$ = Transboundary Water Quality Objective.

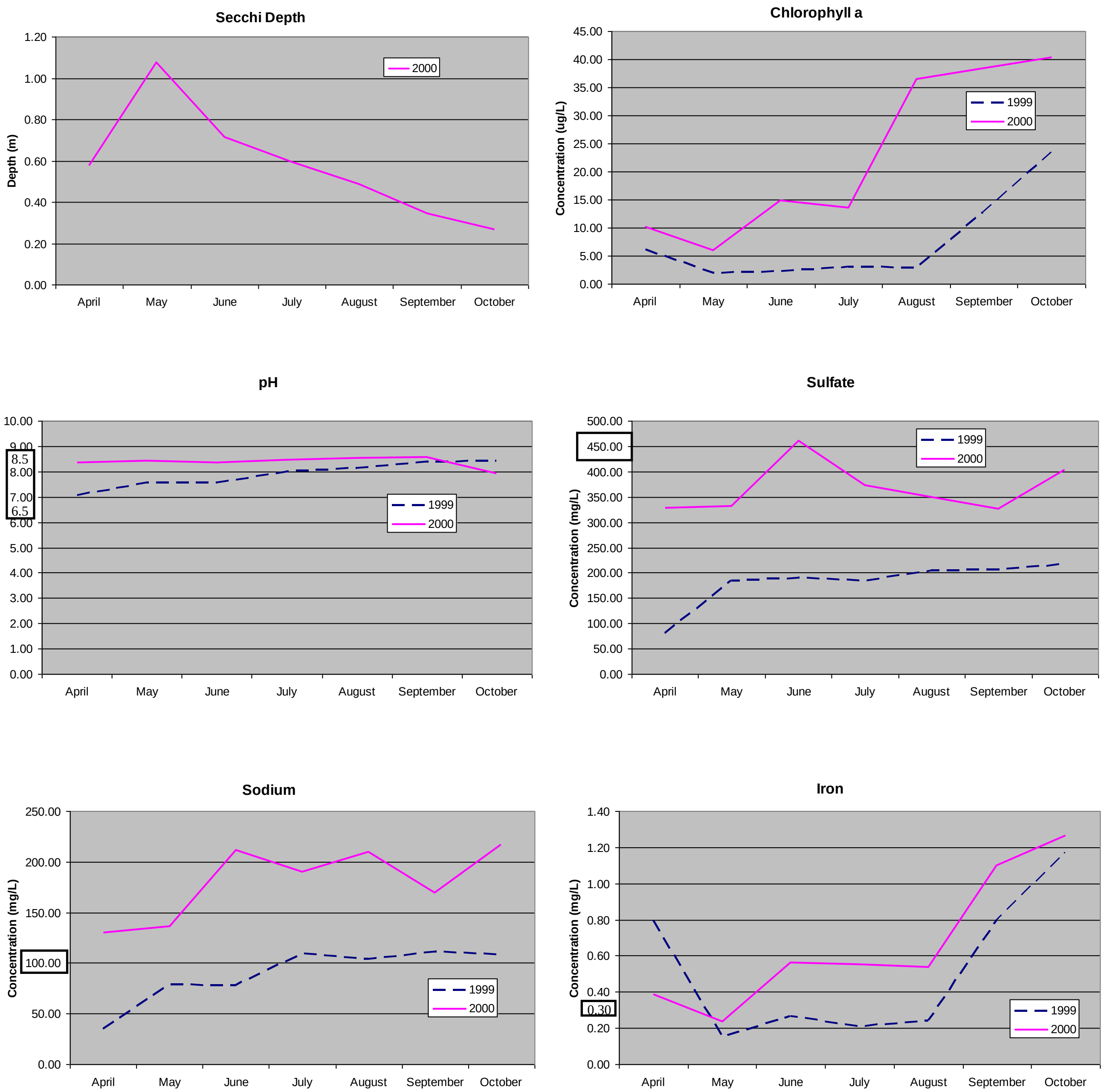


Figure 15. Cont… ▭ = Transboundary Water Quality Objective.

<u>Trophic Status</u> - Concentrations of Chlorophyll a, total P, and secchi disk measurements were used to calculate trophic status indexes (TSI) for the refuge in 2000. TSI in 1999 was calculated using chlorophyll and phosphorus concentrations only. TSI scores were calculated for the Refuge aquatic system as a whole, and do not represent individual pools (Figs 16). Chlorophyll TSI in 1999 was lower than in 2000. The phosphorus TSI and the average TSI did not differ between years.

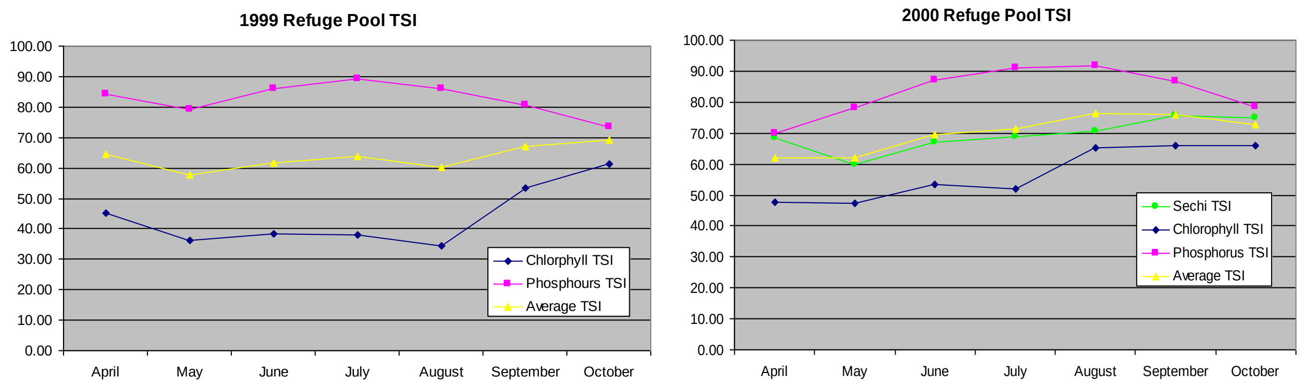


Figure 16. Trophic Status Index (TSI) for pools on J. Clark Salyer, NWR, North Dakota, 1999 and 2000. 0-39 = Oligotrophic, 40-49 = Mesotrophic, 50-69 = Eutrophic, and ≥70 = Hypereutrophic.

Total N to total P ratios in 1999 indicate that all five pools were nitrogen limited for much of the year (Figure 17). In 2000, the total N to total P ratio indicated the pools were slightly P limited early in spring, becoming N limited mid-summer through fall (Figure 18).

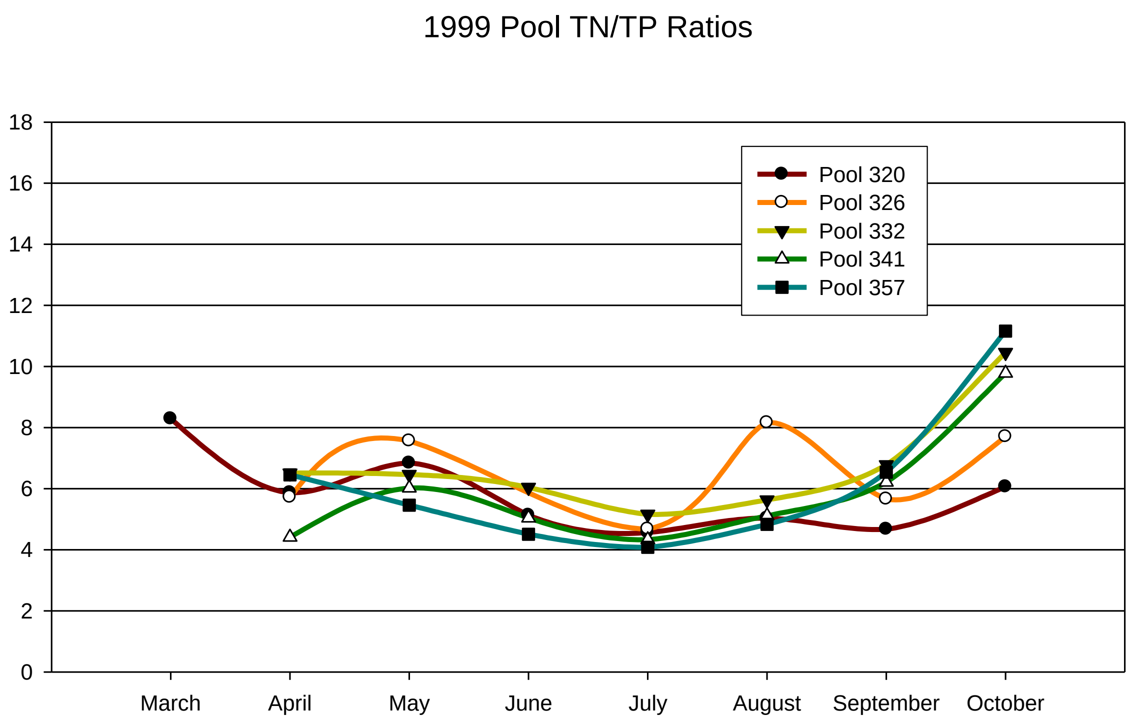


Figure 17. Monthly Total Nitrogen to Total Phosphorus ratios for each pool on J. Clark Salyer NWR, North Dakota, 1999. <10 = Nitrogen limited, >20 = Phosphorus limited.

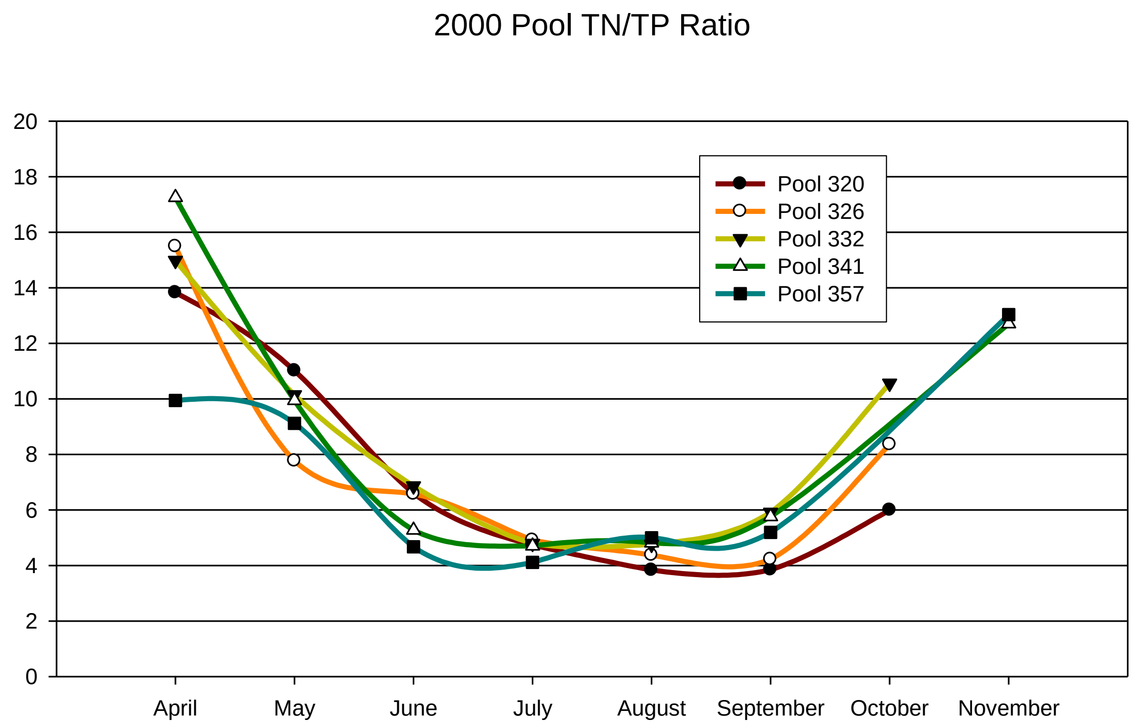


Figure 18. Monthly Total Nitrogen to Total Phosphorus ratios for each pool on J. Clark Salyer NWR, North Dakota, 2000. <10 = Nitrogen limited, >20 = Phosphorus limited.

Nutrient Flux From Pool Sediments - Concentrations of measured parameters differed in the water columns inside vs. outside the tubes (Fig 19). As levels of DO inside the tubes decreased, concentrations of dissolved P, inorganic N, and total N increased. Concentrations of these parameters outside the tubes and under aerobic conditions remained fairly constant throughout the five day sampling periods.

Rate (mg/m^2/d) of dissolved P release from isolated sediments within the in-situ tubes was calculated as the linear change in dissolved P mass in the overlying water column, divided by time and area of the isolation tube. Mass of dissolved P released from sediments in each pool under in-situ conditions subjected to increasing anoxic conditions is shown in Figure 20. In general, July had slightly greater fluxes of dissolved P than June. The mean dissolved P flux across all nine sites (five pools) in June and July was 53.63 mg/m^2/d and 64.08 mg/m^2/d, respectively. Sediments in Pools 320 and 341 actually had negative fluxes of dissolved P from the water column to the sediments during June.
.

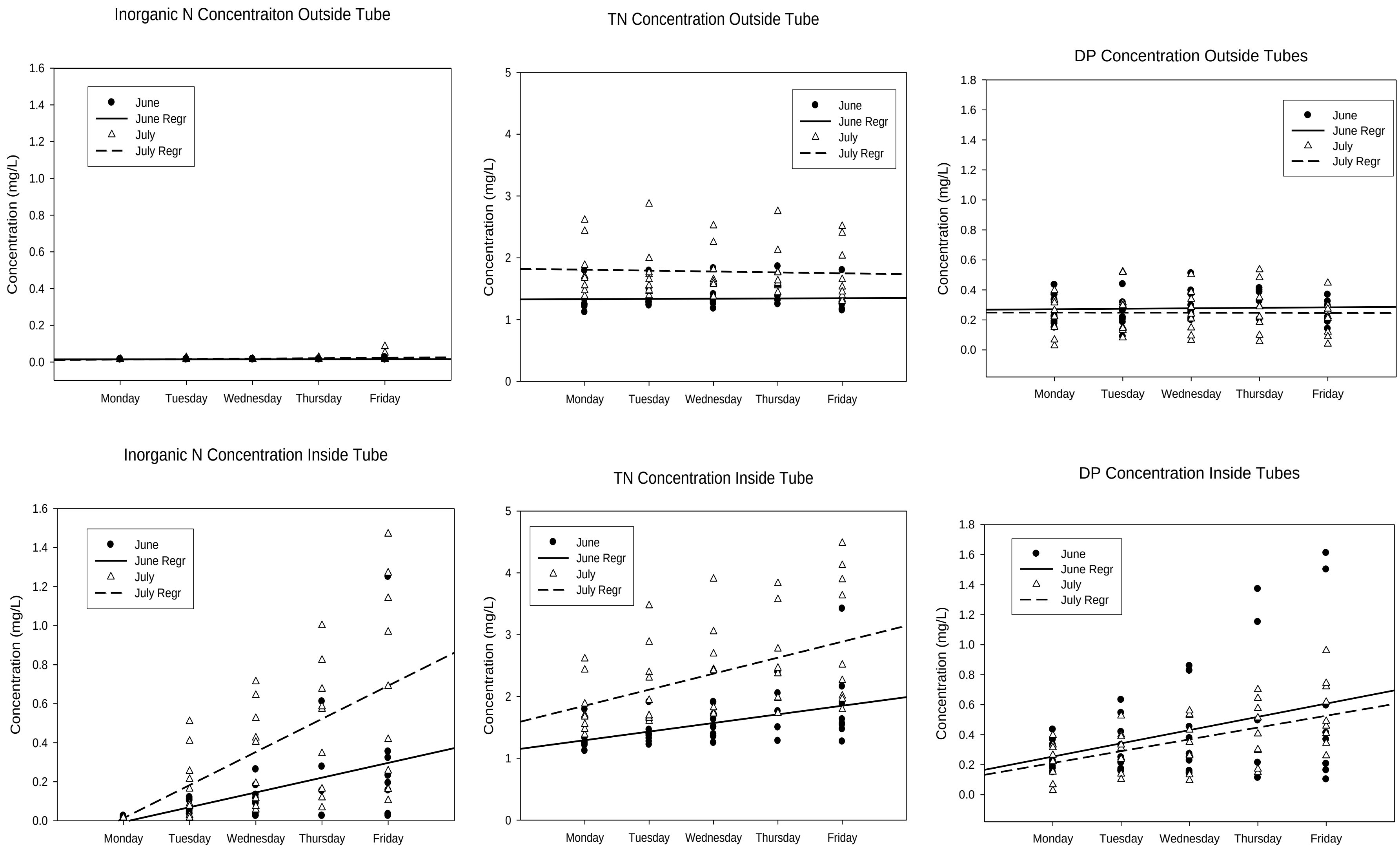


Figure 19. Concentrations of Dissolved Oxygen (DO), Inorganic Nitrogen (ammonia + nitrate/nitrite), Total Nitrogen (TN), and Dissolved Phosphorus (DP) in pool water outside vs. inside of in-situ tubes on J. Clark Salyer NWR, North Dakota, 2001

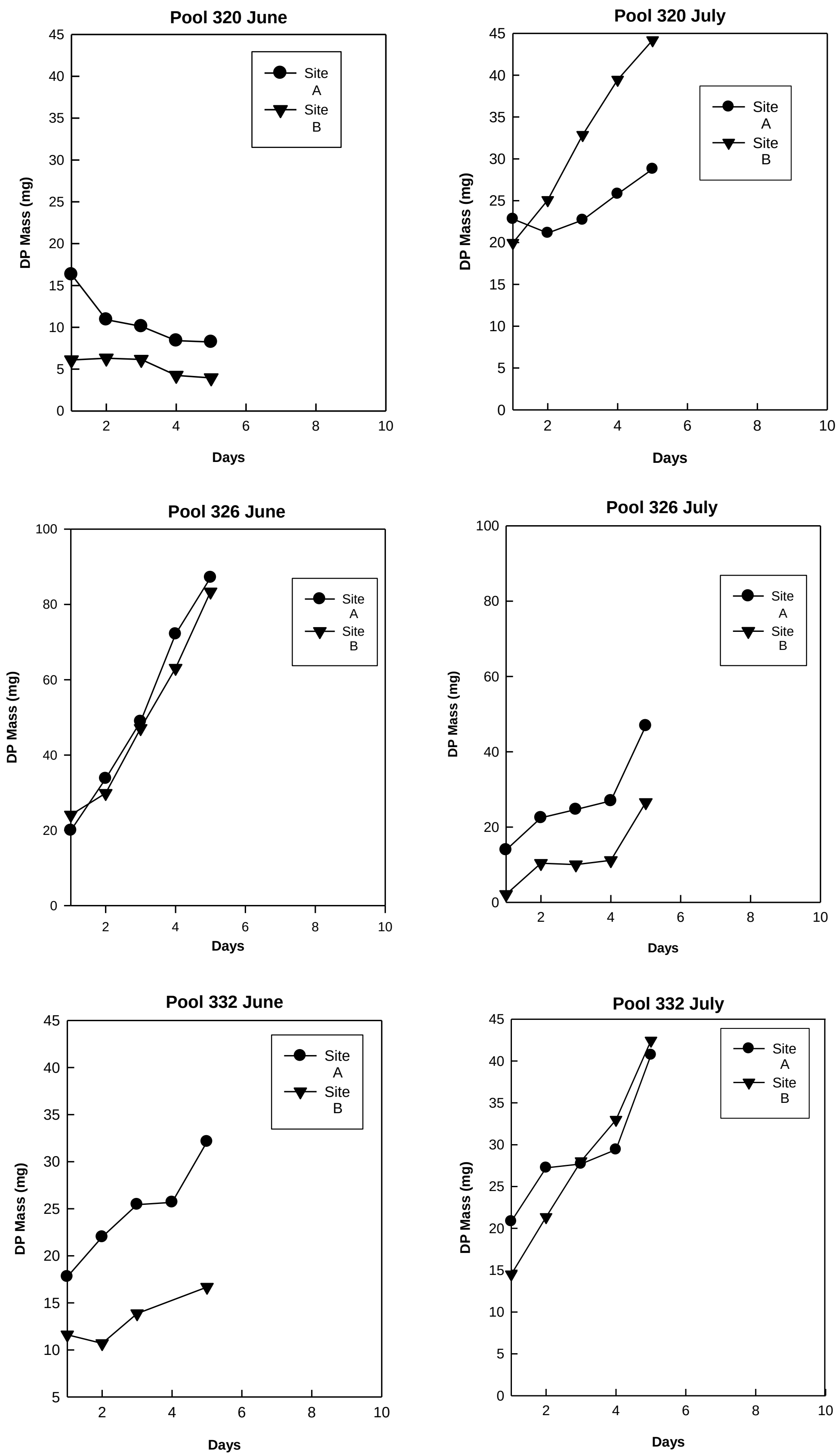


Figure 20. Changes in Dissolved Phosphorus (DP) mass as a function of time in in-situ pool sediments subjected to increasing anoxic conditions on J. Clark Salyer NWR, North Dakota, 2001.

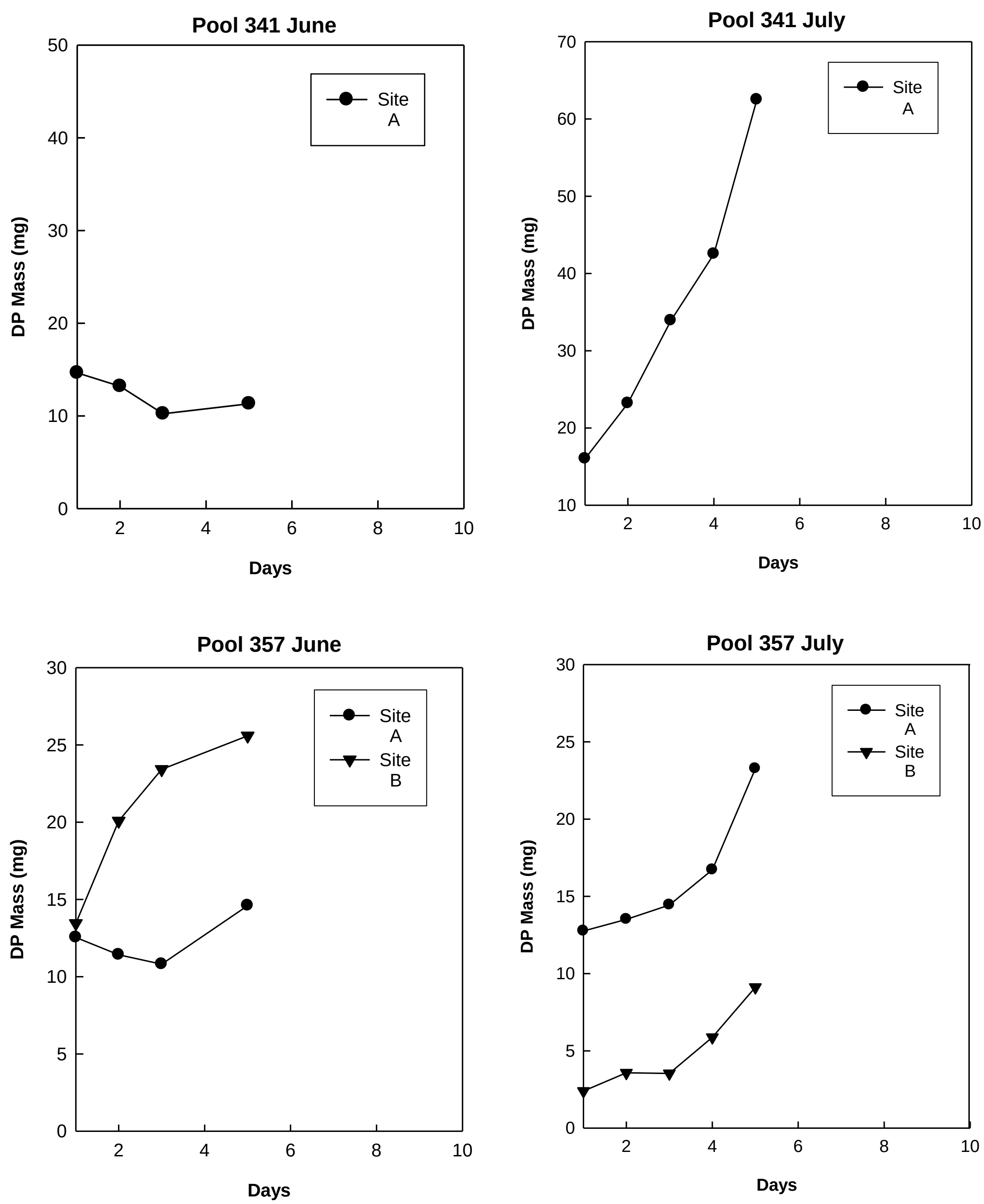


Figure 20. Cont...

DISCUSSION

Nutrient Budget

Of the three sources of nutrients studied in this investigation (inflows, atmospheric wet deposition, and snow geese), inflows were the significant source of nutrient loading to J. Clark Salyer National Wildlife Refuge (Table 15). The Refuge appears to be acting as storage for inorganic N. In 1999, nearly 360,000 kg of inorganic N were loaded to the refuge, while a little over 35,000 kg was exported from the Refuge via the Souris River (Table 15). This resulted in a net gain of 323,873 kg of inorganic N sequestered in Refuge pools. This also was true in 2000, where 74,305 kg were retained. Additionally in 2000, a low-flow year, 15.9 million kg of TDS, 18.9 million kg of SO_4 and 3.5 million kg of Na were retained in the Refuge.

The amount of nutrients (kg/yr) exported from the Refuge in 1999 was dramatic: a 60% increase in total N, 149% increase in total P, 71% TDS, 53% SO_4, and 100% increase in Na (Table 15). In 2000, only total N and total P were exported (4% and 83%, respectively). There are several possible explanations for the difference between nutrient amounts loaded to the Refuge vs. amounts measured downstream of the Refuge.

Results of in-situ sediment testing do reveal the sediments in pools on the Refuge, under increasingly anoxic conditions, flux large amounts of nutrients to the above water column. These results, however, represent sediment flux potential and not what is actually occurring in the pools. Firstly, this is because measurements during the in-situ testing were collected under artificial increasingly anoxic conditions. The lowest mean DO levels measured in the in-situ tubes was 1.9 mg/L (n=18, SE$\pm$0.45). Dissolved oxygen at this level was rarely measured in any of the ambient sampling during 1999 or 2000. In fact, of all the DO measurements taken during the 2 years (n=206), levels below 3.0 mg/L were measured only once in the inflows, three times in the pools, and once in the outflow at Coulter. Secondly, all the measurements were collected during daylight hours; yet water bodies have a daily, or diurnal, pattern for temperature and DO. During the heat of day algal and plant activity, through photosynthesis, are pumping oxygen into the system. At night, photosynthesis stops and the system consumes oxygen. Thus, any actual nutrient fluxes were likely occurring outside of the sampling periods. Depending upon the severity of oxygen depletion during the nights, actual nutrient fluxes could be more or less than those recorded within the in-situ tubes. Lastly, while the results of this investigation demonstrate sediments are fluxing nutrients to the above water column, the quantity of those nutrients being transported through the Refuge and ultimately measured at Coulter is still unknown.

Although no data collection occurred during winter periods, it is important to mention nutrient flux from sediments in under-ice conditions. Dramatic decreases in DO are common during winter periods when water bodies are ice covered. These anoxic conditions are often associated with shallow, stagnant areas, away from the river channel and flowing water. In the Refuge pools where in-situ testing revealed nutrient fluxes associated with low DO, it is likely nutrients are being fluxed from the sediments in under-ice conditions. These newly released nutrients could then be slowly flushed through the Refuge during winter low-flows and/or dramatically flushed during high spring flows. Alleviating anoxic conditions under ice is discussed below in Management Recommendations.

Another possible explanation for the increases in nutrients seen downstream of the Refuge vs. inflows could be an underestimated fall population of snow geese using the Refuge, resulting in an underestimate of nutrient amounts contributed by geese. The population numbers used in this investigation are estimates based on observations by Refuge personnel. Thus, to eliminate bias from a possible underestimate of populations in 1999 and 2000,

one can substitute the population numbers from
1994, a peak

Table 15. Nutrient budget for J. Clark Salyer NWR, North Dakota, 1999-2000.

Loading Sources (1999)	NH_3 kg/yr	NO_2+NO_3 kg/yr	Total Kjeldahl N kg/yr	Total N kg/yr	Total P kg/yr	Dissolved P kg/yr	Total Dissolved Solids kg/yr	Total Suspended Solids kg/yr	SO_4 kg/yr	Na kg/yr
Inflows	55.2[a]	259.7	1,360.7	1,606.0	266.5	220.4	655,078.5	69,489.1	243,927.5	102,427.9
Wet Deposition	14.9	29.6		44.5					20.2	0.784
Snow Geese		0.01		2.0	0.3					
Total Load to Refuge	70.1	289.3	1,360.7	1,652.5	266.8	220.4	655,078.5	69,489.1	243,947.7	102,428.7
Souris River Out[b]	7.8	27.8	2,611.9	2,639.7	664.3	371.9	1,121,832.0	N/A	373,052.6	205,092.1
1999 Budget: Load Out - Load in	**-62.4**	**-261.5**	**1,251.2**	**987.3**	**397.6**	**151.5**	**466,753.5**	**N/A**	**129,104.9**	**102,663.4**
Loading Sources (2000)										
Inflows	6.7	19.5	246.8	265.5	45.4	34.9	158,343.0	20,461.2	66,245.3	29,550.0
Wet Deposition	17.8	34.8		52.6					38.4	8.0
Snow Geese		0.01		4.4	0.6					
Total Load to Refuge	24.5	54.3	246.8	322.5	46.0	34.9	158,343.0	20,461.2	66,283.8	29,558.0
Souris River Out[b]	1.0	3.5	331.6	335.1	84.3	47.2	142,408.9	N/A	47,356.4	26,035.0
2000 Budget: Load Out - Load in	**-23.5**	**-50.8**	**84.8**	**12.6**	**38.3**	**12.3**	**-15,934.1**	**N/A**	**-18,927.4**	**-3,523.0**

[a] Kg x 1000
[b] Measured at Coulter, Manitoba.

population year. In 1994, the average number of snow geese using the Refuge every week from the end of September till the third week in November was 123,750 (Table 8). A population of snow geese this size would load 10,215 kg of total N and 1,362 kg of total P to the Refuge. This is still less total N than calculated from atmospheric deposition, and the potential total P increase still is not enough to explain the large difference found between inflow and outflow loading.

Snow geese alone do not provide a complete picture of nutrient contribution from waterfowl. As noted earlier in this report, the Refuge can have 500,000 or more ducks using the Refuge during fall migration. Not all of those ducks will be contributing nutrients to the Refuge; many are wetland feeding species and will only be cycling nutrients already in the system. Species such as mallard (*Anas platyrhynchos*) and northern pintail (*Anas acuta*) readily feed in croplands and thus will be the species that primarily bring new nutrients back to the Refuge (Clark and Sugden 1990, Austin and Miller 1995).

In assessing duck contribution to nutrient loading, the following assumptions and knowns were used to calculate nutrient contribution from ducks:

- Field feeding ducks exhibit morning and evening feeding patterns (Drilling et al. 2002, Austin and Miller 1995) similar to snow geese.
- During field work for this investigation, field feeding ducks were observed feeding in harvested small grain fields.
- Field feeding ducks are assumed to comprise 65% of the duck population using the Refuge during fall (pers. comm., B. Howard, J. Clark Salyer NWR).
- Duck population trends (e.g. arrival, peak, departure) are assumed to follow those observed for snow geese.
- A mallard produces 2.25% - 3% of body mass in grams of dry mass fecal material per day (Anderson et al. 2003, Sherer et al. 1995). The conservative figure of 3% was used.
- Nitrogen and phosphorus content of mallard fecal material is 2.62 % - 3.5% and 1.32% - 1.4%, respectively (Anderson et al. 2003, Marion et al. 1994). The conservative figures of 3.5% for N and 1.4% for P were used.
- Gut transit time for mallards is very quick (Drilling et al. 2002). The same transit time as snow geese was used in computations.

Thus, for a 1200 g duck (Drilling et al. 2002), a daily production via excreta is calculated as 1.3 g of total N and 0.5 g total P. These values are reasonable, given the excreta production and nutrient content of 0.9 - 2.6 g N and 0.4 – 0.6 g P used in other studies (Marion et al. 1994, Pettigrew et al. 1998, Gwiazda 1996). Fifty-eight percent of the fecal material excreted per day is assumed loaded to the Refuge (similar to snow geese), thus nutrient loading to the Refuge from a single field feeding duck is 0.75 g N and 0.3 g P per day. If 65% of the total duck population is field feeding, the calculated contribution from ducks is 1,697 Kg total N and 679 Kg total P to the Refuge over the course of fall migration.

A new budget table can now be formulated where the contributions from ducks and maximum snow goose populations, as described above, are combined (Table 16). It's clear that waterfowl populations (snow geese and ducks) are not significant contributors of nutrients to the Refuge compared to inflows and atmospheric deposition. Even maximizing population numbers does not equate to significant nutrient inputs.

Several studies on waterfowl contribution to nutrient levels in bodies of water have shown that results are dependant upon food types the birds feeds on, weather, numbers of birds, species of birds, and time spent on the body of water (Manny et al. 1975, Brandvold et al. 1976, Manny et al. 1994, Marion et al. 1994, Scherer et al. 1995, Pettigrew et al. 1998, Post et al. 1998).

Table 16. Revised Nitrogen and Phosphorus budgets taking into account maximum potential waterfowl (snow geese *and* ducks) contribution to nutrient loading on J. Clark Salyer NWR, North Dakota, 1999-2000.

Loading Sources (1999)	Total N KG/YR	Total P KG/YR
Inflows	1,606.0[a]	266.5
Wet Deposition	44.5	
Waterfowl	11.9	2.0
Total Load to Refuge	1,662.4	268.5
Souris River Out[b]	2,639.7	664.3
1999 Budget: Load Out - Load in	**977.3**	**395.8**
Loading Sources (2000)		
Inflows	265.5	45.4
Wet Deposition	52.6	
Waterfowl	11.9	2.0
Total Load to Refuge	330.0	47.5
Souris River Out[b]	335.1	84.3
2000 Budget: Load Out - Load in	**5.1**	**36.9**

[a] Kg x 1000
[b] Measured at Coulter

These studies had results ranging from significant contribution to insignificant contributions based on the above criteria. The current investigation supports these previous studies, showing that singularly large numbers of
concentrated waterfowl do not necessarily equate to significant nutrient loading.

Observations during field work confirmed that geese fed exclusively on small grains. If crops with higher nutrient content (e.g., corn, peas, or beans) become a more readily available food stuff, waterfowl contribution of nutrients to the Refuge would likely change (all else staying the same). However, this study shows that compared to both inflow and atmospheric contributions, waterfowl contributions are quite small and a change in food type will likely not create a significant shift upward for waterfowl contribution overall.

Hunting pressure can affect waterfowl contribution by disturbing feeding birds or causing longer flights to feeding grounds (Frederick and Klaas 1982). Hunting activities were not observed to have had these affects on the flocks monitored during this study.

While not found to contribute nutrients significantly to the refuge overall, waterfowl could contribute excessive amounts of nutrients to a single, or a few pools, depending upon where they roost (spread out or on just one pool). Waterfowl were not observed to concentrate in localized areas; rather individual flocks were spread out upon several pools.

A plausible explanation for the large concentrations of nutrients measured downstream at Coulter (especially in 1999) may be from a discrepancy in water sampling schemes. During the 8-month sampling period (March-October) in 1999, most inflows were sampled at least once in 7 of the 8 months (Boundary Creek was sampled 6 out of the 8 months) (Table 17). However, flows downstream of the Refuge, measured in the Souris River at Coulter, MB, were sampled only 3 of these 8 months (July, Sept., and Oct.). 1999

was an extremely high-flow year; 78% of the
downstream flow in the Souris River occurred

Table 17. Number of times (x) per month water samples were collected for each inflow to, and downstream of J. Clark Salyer NWR, North Dakota, 1999-2000.

	Inflow						Downstream
Month	**Souris River at Bantry**	**Willow Creek**	**Stone Creek**	**Cut Bank Creek**	**Deep River**	**Boundary Creek**	**Souris River at Coulter, MB**
1999							
January							x
February							
March				x	x		
April*	xx	xx	xxx	xx	x	xxx	
May*	xx	xx	xxx	xxx	xx	xxx	
June*	x	x	x	x	x	x	
July	x	x	x	x	x	x	x
August	xx	x	x	x	xx	x	
September	xx	xx	x	x	xx	x	xx
October	x	x	x				x
November							
December							x
2000							
January							
February							x
March							
April	x	x	x	x	x	x	x
May	x	x	xxx	xxx	x	xxx	x
June	xx	xx	xx	xx	xx	xx	x
July	x	x	[a]	[a]	x	x	x
August	x	x	[a]	[a]	x		
September	x	x	[a]	[a]	x	x	x
October	x	x	[a]	[a]	x		x
November	x	x	[a]	[a]	x	x	
December							x

* 78% of all tributary flows in 1999 occurred during these months.
[a] Samples were not collected due to lack of flow.

April – June (Harkness et al. 1999 and 2000). Yet water quality samples were not collected during this time at Coulter in 1999. In year 2000, sample collections on the inflows and downstream flow were sampled in more comparable months (Table 17).

Bias in a loading estimate can come from unrepresentative sampling (Walker 1998). Unrepresentative sampling results from differences in the distribution of flows between the sampling dates and the entire averaging period. This was the case in 1999, where the average downstream flow during water sampling at Coulter was 565 cfs, yet the entire averaging period flow was 1,582 cfs. The maximum flow sampled in 1999 at Coulter was 1,469 cfs – much less than the recorded maximum flow of 6,980 cfs. The minimum flows sampled (129 cfs) also were unrepresentative of the minimum recorded in 1999 (39 cfs). In 2000, sampled flows vs. recorded flows for the whole year were very similar, e.g., average = 248 cfs vs. 200 cfs; maximum = 663 cfs vs. 670 cfs; and minimum = 17 cfs vs. 8.1 cfs, respectively. The unrepresentative sampling in 1999 vs. representative sampling in 2000 is reflected in the loading estimates (Table 15), where 2000 loads at Coulter are more reasonable with input loads.

Additionally, the 6-mile stretch of river between the Refuge's outfall at dam 357 and the Coulter sampling site is more characteristic of a lentic vs. lotic system. This 6-mile stretch of the river is more akin to an extension of the Refuge's last pool. Internal cycling along this stretch of river cannot be ruled out without further study as a source of additional nutrients measured at Coulter.

Transboundary Water Quality Objectives

The Refuge has on occasion been targeted by State and local agencies as a contributor or Source of the downstream exceedences in Transboundary Water Quality Objectives. The results of this investigation do not support that assertion. A review of Tables 9 and 10 shows that in no instance did an exceedence occur downstream of the Refuge, at Coulter, that wasn't also measured in the inflows prior to entering the Refuge. In fact, during 1999, the mean inflow concentrations exceeded the mean concentrations measured across the Refuge pools in all parameters except total P and Na (Figure 21). In 2000, mean inflow concentrations exceeded mean Refuge concentrations in all parameters except total P and Fe (Figure 22). When the concentrations measured at Coulter did exceed Refuge concentrations, they were at such a greater magnitude as to suggest an additional source(s) is contributing to the high values measured at Coulter (Figures 21 & 22). These figures demonstrate that J. Clark Salyer Refuge and its pools as a whole in 1999 improved water quality concentrations for total N, fecal coliforms, Fe, TDS, and SO_4; and did little to affect concentrations for total P or Na. In 2000, the refuge functioned to improve concentrations of total N, fecal coliforms, Na, TDS and SO_4.

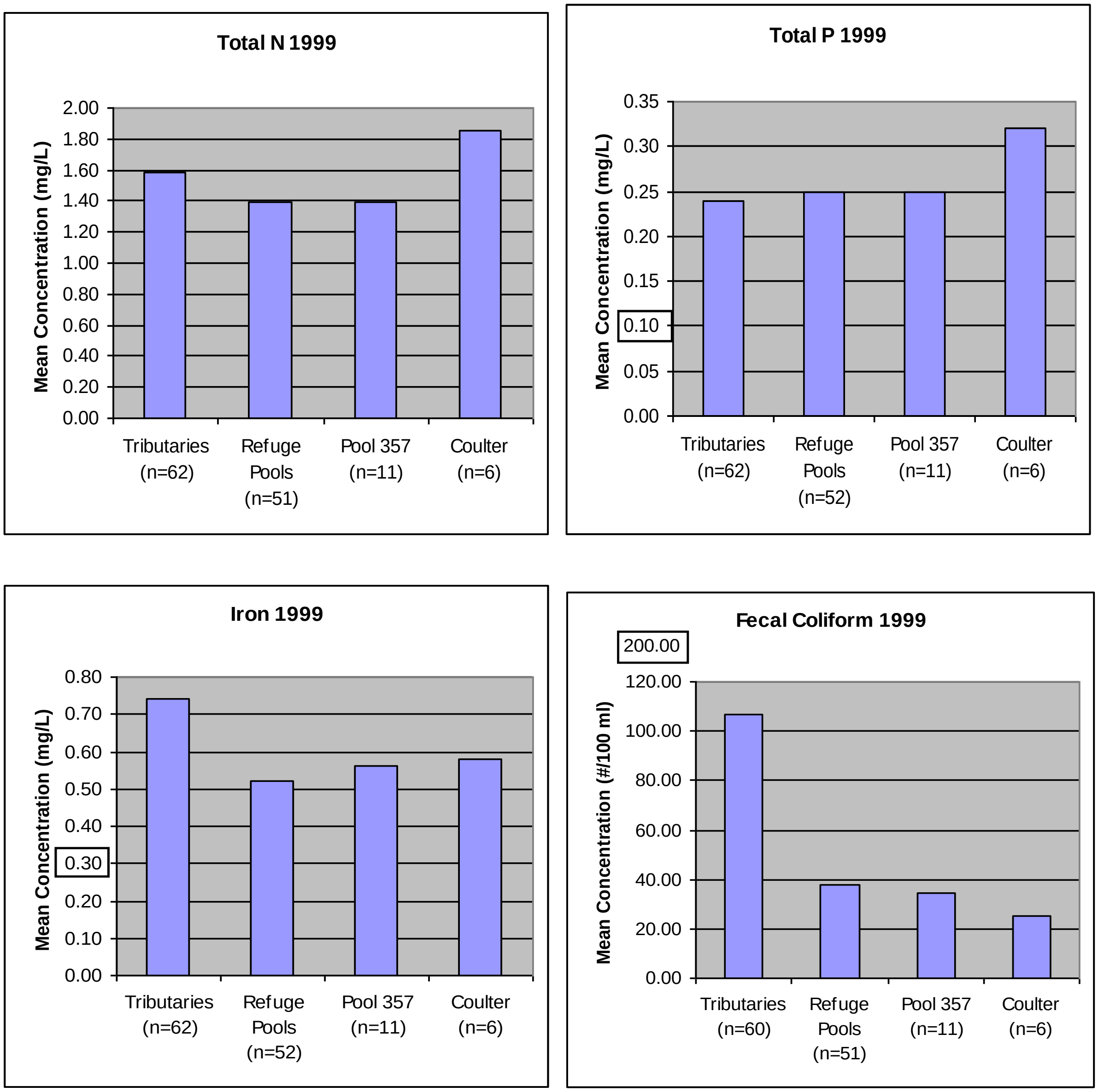
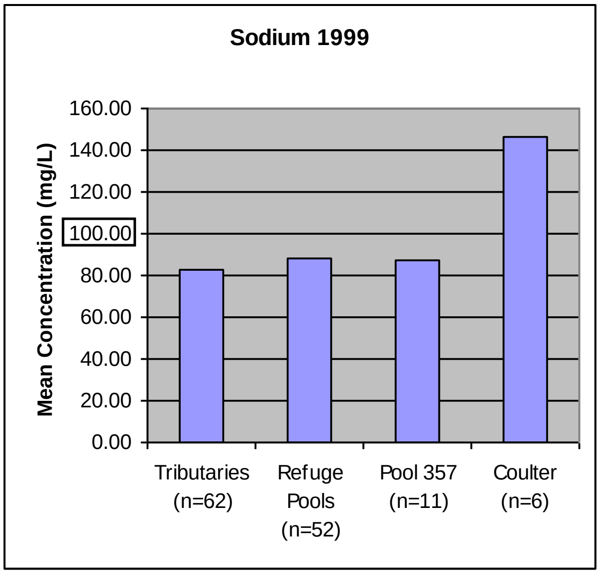
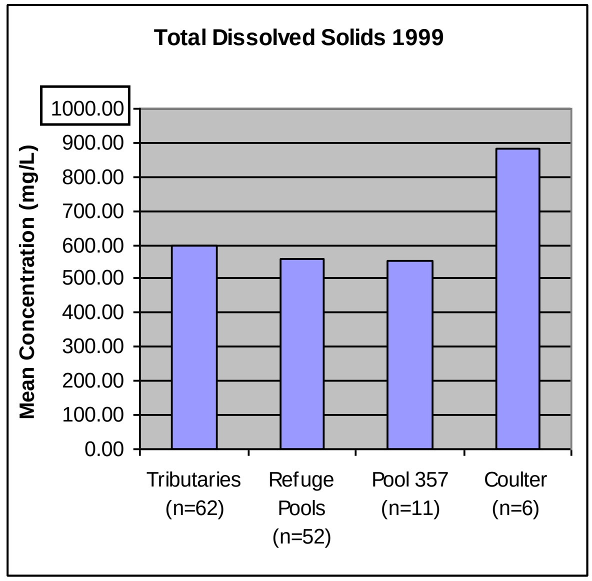


Figure 21. Mean yearly water quality parameter concentrations from six tributaries, five refuge pools, and Pool 357 on J. Clark Salyer NWR, North Dakota, and the Souris River at Coulter, Manitoba, 1999 ($\boxed{}$ = Transboundary Water Quality Objective).





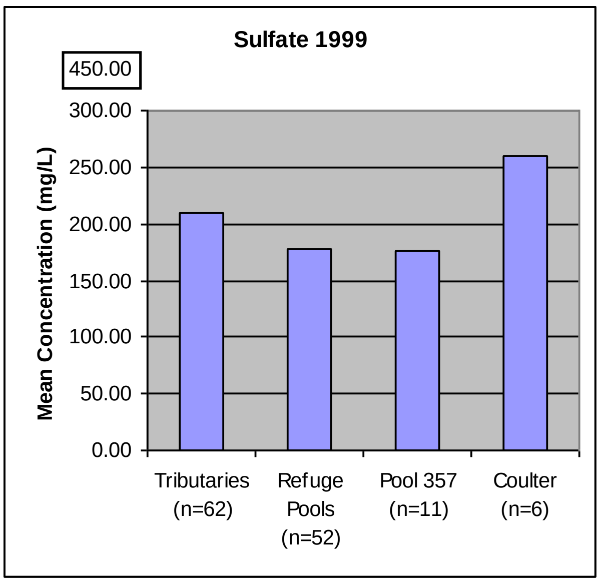


Figure 21. Cont…

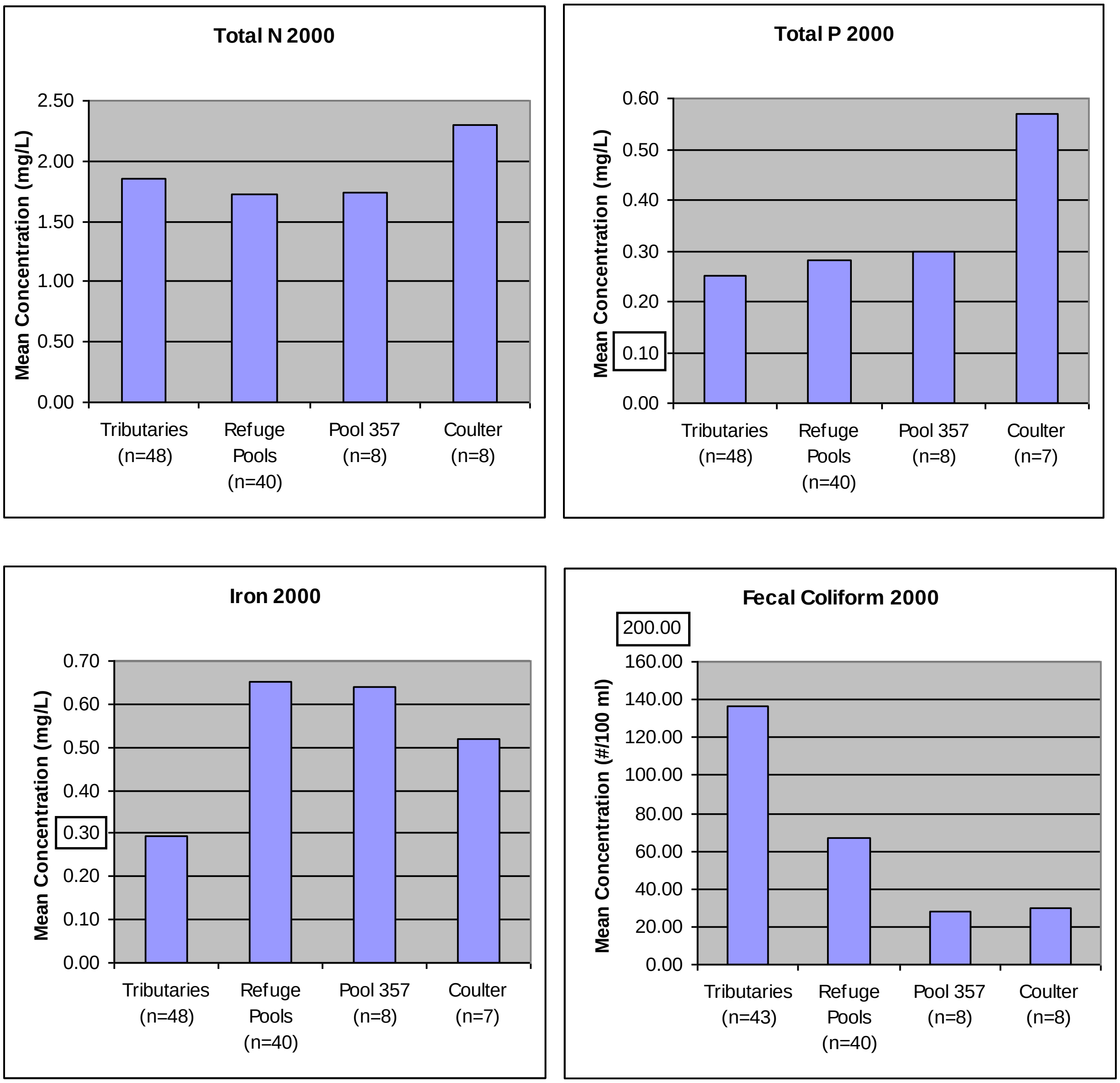
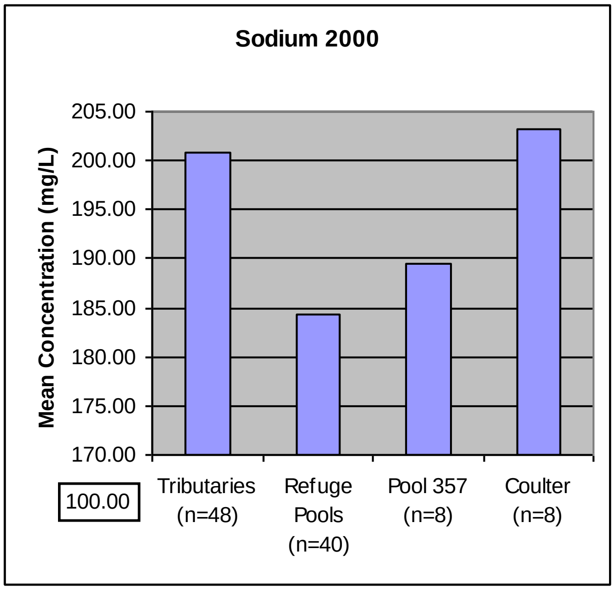
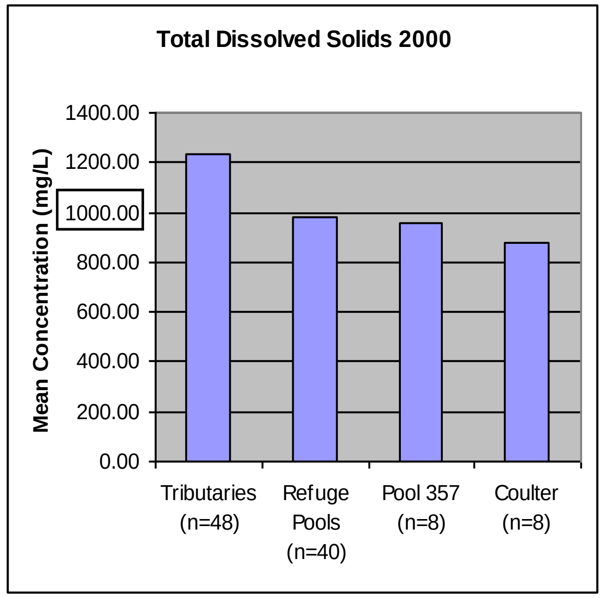


Figure 22. Mean yearly water quality parameter concentrations from six tributaries, five refuge pools, and Pool 357 on J. Clark Salyer NWR, North Dakota, and the Souris River at Coulter, Manitoba, 2000 (= Transboundary Water Quality Objective).





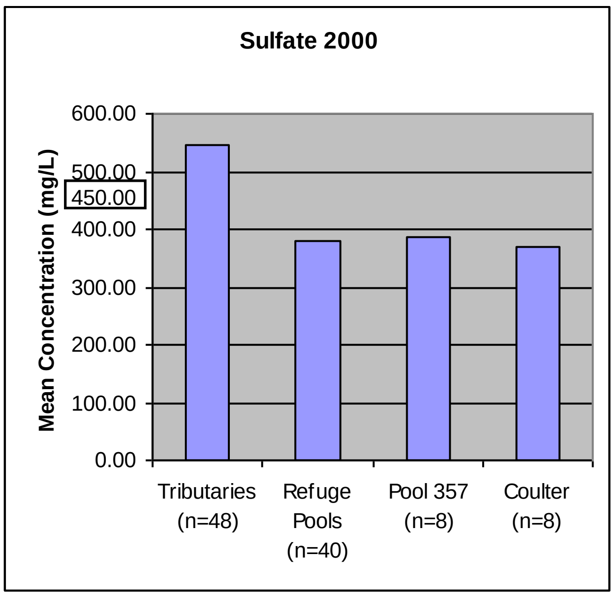


Figure 22. Cont…

Trophic Status

According to the North Dakota Department of Health, 32% of 128 lakes assessed in the state are mesotrophic, 48% eutrophic, and 20% hypereutrophic (Draft - North Dakota 2008 Integrated Section 305(b) Water Quality Assessment Report and Section 303(d) List of Waters Needing Total Maximum Daily Loads). Nutrients were identified in the Department of Health's report as being the third most prevalent source threatening or impairing a body of water: "Major sources of nutrient loading to the state's lakes and reservoirs are erosion and runoff from cropland; runoff from animal feeding operations (e.g., concentrated livestock feeding and wintering operations); and hydrologic modifications. Hydrologic modifications, such as wetland drainage, channelization and ditching, increase the runoff and delivery rates to lakes and reservoirs, in effect increasing the size of a lake's watershed."

A ratio of total nitrogen to total phosphorus concentrations is an index of nutritional status of phytoplankton. Total nitrogen to total phosphorus concentrations in the Refuge pools during 1999 were between 4:1 and 8:1 for most of the sampling period (Figure 17). In 2000, the ratios were between 10:1 and 18:1 in spring and fall (Figure 18). The nitrogen to phosphorus ratios that year during the summer months had dropped to between 4:1 and 6:1. The Department of Health uses a total N/total P ratio of 15:1 as an indicator of equilibrium. A ratio <10 means the water body is nitrogen limited (deficient) and >20 indicates P limited. Excess phosphorus increases algal and macrophyte activity and the uptake of scarce nitrogen. This gives an advantage to nitrogen fixing organisms like species of bluegreen algae.

Trophic Status Index (TSI) values (Carlson 1977) were calculated for total phosphorus and chlorophyll in 1999; and for total phosphorus, chlorophyll, and secchi disk transparency in 2000 (Figure 16). If phosphorus and secchi disk TSI values are relatively similar and higher than the chlorophyll TSI value, then dissolved color or non-algal particulates dominate light attenuation (Carlson and Simpson 1996). It follows that, if the secchi disk and chlorophyll TSI values are similar, then chlorophyll is dominating light attenuation (Figure 23).

The calculated chlorophyll TSI in 1999 was less than the phosphorus TSI, and in 2000, the chlorophyll TSI was less than both the phosphorus and secchi TSI's. This supports that excess algae production was likely not occurring, and suspended sediment/organic material was causing any light attenuation when measured in the pools. When turbidity is high, the chlorophyll index is commonly 10 to 20 units below the phosphorus or secchi depth TSI's (Carlson 1992).

Based on TSI's and water quality data collected from the pools, the Refuge as a whole was generally assessed as a boarder-line mesotrophic/eutrophic aquatic system (Figure 16). This is not to say Refuge water quality is poor. An unfortunate misconception concerning trophic state is that the term is synonymous with the concept of water quality. The following is an excerpt from Carlson and Simpson (1996).

> "Although trophic state and water quality are related, the two terms should not be used interchangeably. Trophic state simply describes biological condition of a water body. Whether oligotrophic or eutrophic, a lake has attributes of production that remain constant no matter what the use of the water or where the lake is located. For the trophic state terms to have meaning at all, they must be applicable in any situation in any location."
>
> "Water quality, on the other hand, is a term used to describe the condition of a water body in relation to human needs or values. Quality is not an absolute. The terms "good" or

"poor" water quality only have meaning relative to the use of the water and the attitude of the user. An oligotrophic lake might have good water quality for swimming, but be considered poor water quality for bass fishing. Therefore, the term trophic state should not be used to infer quality."

A eutrophic aquatic system better serves the purpose of the Refuge (providing habitat for waterfowl, migratory birds, and other wildlife) than an oligotrophic system. This investigation does not suggest that current trophic status of the system is such that it negatively affects the Refuge's purpose. However, if current nutrient loading to the Refuge continues, and/or a prolonged anoxic condition occurs during the growing season fluxing large quantities of ortho-phosphate into the water column, there is a possibility the system can become "over-productive" (hypereutrophic) and decrease habitat quality. These situations also would exacerbate any water quality exceedences downstream of the Refuge.

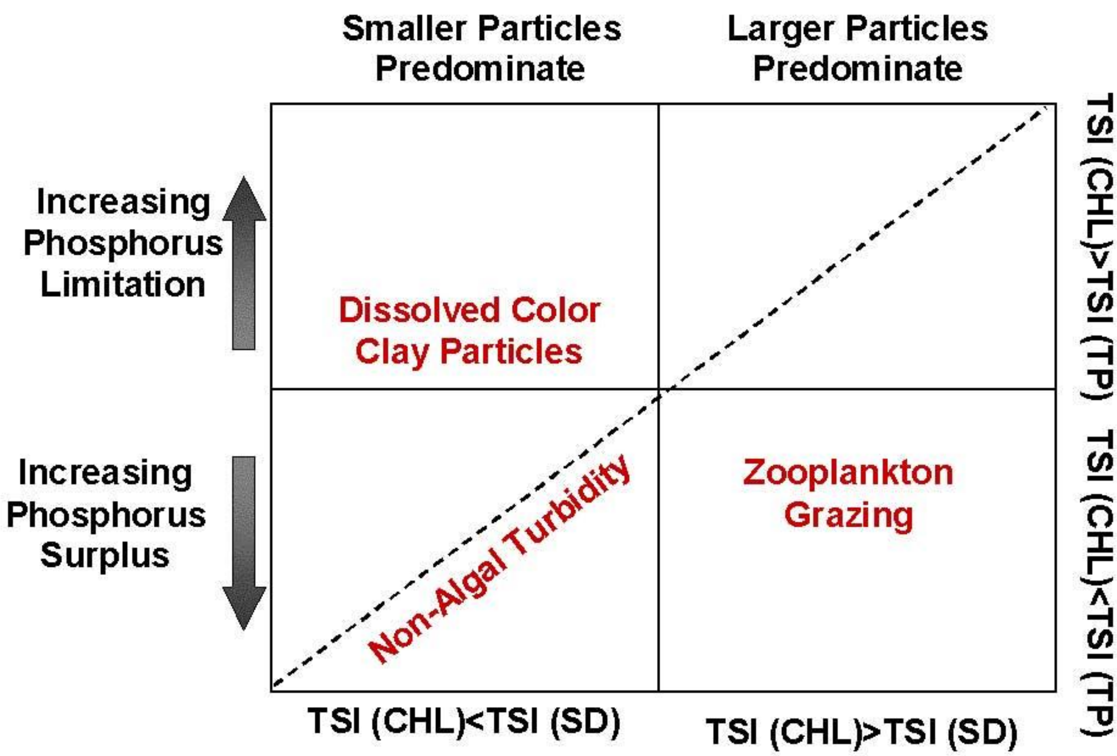


Figure 23. A representation of possible explanations of deviations of the Trophic State Index equations (Carlson and Simpson 1996).

MANAGEMENT RECOMMENDATIONS

The Refuge recently completed a Comprehensive Conservation Plan (CCP) setting direction and management goals (http://www.fws.gov/mountain-prairie/planning/ccp.htm). The CCP's Wetland Goal is: "Manage riverine wetlands, including marshes and lakes, to sustain the long-term capacity of riverine wetlands to support diverse plant and wildlife communities. Restore ecological processes that sustain long-term productivity of wetlands". Results gleaned from the current investigation support many of the strategies outlined in the CCP to accomplish this wetland goal. The investigation results also demonstrate the importance of considering affects of management decisions on water quality.

A strategy in the CCP is to use information derived from various sources to develop predictive models that determine effects of water management (especially hydroperiod) on wetland plants, invertebrates, and migratory birds. Information collected in this investigation can be used as a base-line, along with other biological indicators outlined in the CCP when evaluating and comprehending crucial ecological processes that maintain long-term wetland productivity. Any predictive model should incorporate effects on water quality/trophic state changes, as these changes will have direct impacts on wetland plants, invertebrates, etc.

The CCP discusses introducing efforts on a watershed level that reduce sedimentation and nonpoint source pollution and/or their effects on the Refuge. Under both a high-flow and low-flow year, Willow, Stone, and Boundary Creeks consistently had high concentrations of nutrients, ions, dissolved and suspended solids, and fecal coliforms (Tables 9 and 10). All three watersheds should be targeted for clean-up, with priority given to Willow Creek watershed. Priority efforts in Willow Creek watershed should produce the greatest benefit/effort to the Refuge. Willow Creek not only consistently had high concentrations, it also ranked second in terms of total loading (Table 11). The USDA's NRCS has an Agricultural Non-Point Source watershed model (AGNPS) that identifies significant nonpoint source pollutant sources and assesses relative reductions in nutrient (TN and TP) and sediment loading that can be expected through implementation of best management practices (BMPs) within a watershed (http://www.wsi.nrcs.usda.gov/products/w2q/h&h/tools_models/agnps/index.html).

Shallow, warm water lakes with a history of receiving nutrient-rich inflows, such as the Refuge, are especially likely to maintain high rates of internal cycling of phosphorus even after the external sources have been eliminated or reduced. Any decisions pertaining to management of impoundments and their water supply should consider affects upon internal cycling of nutrients. For example, the CCP recommends studying the economic, physical, and biological feasibility of constructing a major bypass channel to improve management of several impoundments on the Refuge. A bypass channel would aid greatly in reducing sedimentation and nutrient loading to pools and could help to reduce flushing downstream any nutrients fluxed from pool sediments. However, while water quality downstream may improve, nutrient within pools could reach hypereutrophic levels without properly timed flushing. Improving or maintaining current water quality in Refuge pools will likely involve implementation of a combination of recommendations. Keeping in mind, the term "water quality" is subjective and any management options should be implemented with a known objective (e.g., reduced P levels in outflow) in mind.

Dredging of pool sediments is discussed in the CCP. The large amounts of phosphorus that can be fluxed from pool sediments support dredging as a method of sediment and nutrient removal. Consideration should be given to a possible re-suspension of lake sediment, disruption of benthic community, and finding a suitable disposal location. If sediment has low concentrations of toxic metals and/or organic compounds, it can be used as a fertilizer or soil conditioner on agricultural soils returning nutrients to the terrestrial growing cycle.

The ability to predict with certainty the likelihood of success from dredging is lacking. The following is an excerpt from North Dakota Department of Health (2007): "Dredging … should be successful in removing nutrients accumulated in the sediment, but there is no technically defensible method to quantify the anticipated in-reservoir improvement. It seems reasonable to expect a 50% reduction in internal loading by sediment removal." The life expectancy of a dredging project is dependant upon the rate of external loading of nutrients.

High concentrations of available phosphorus are usually associated with sediments of fine-grained silt and clay-sized particles enriched in organic matter. These do not occur evenly distributed throughout a water body, but occur in specific locations. Therefore, before any remediation of sediments is undertaken, the distribution of sediment types should be mapped.
Reducing anoxic conditions within the Refuge pools will prevent large nutrient fluxes from sediments and help reduce exceedences in water quality measurements downstream of the Refuge. Depleted oxygen levels occur during periods of deep snow cover, reducing light penetration under ice. A cost effective method to enhancing oxygen concentrations during winter is removal of snow from ice. Snow removal in strips over areas with water depth <7 feet allows light penetration and production of oxygen by rooted aquatic plants.

REFERENCES

Andersen, D.C, J.J. Sartoris, J.S. Thullen, and P.G. Reusch. 2003. The effects of birds use on nutrient removal in a constructed wastewater-treatment wetland. Wetlands 23(2):423-435.

Angelo, R.T., and K.W. Anderson. 1982. The chemistry of atmospheric precipitation in North Dakota: a preliminary report with comments on the ambient air quality and meteorological characteristics of western North Dakota in 1981. North Dakota Department of Health. Unpublished Report. 143 pp.

Ankney, C. D. 1977. Feeding and digestive organ size in breeding lesser snow geese. The Auk 94:275-282.

Austin, Jane E., and Michael R. Miller. 1995. Northern Pintail (Anas acuta), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North American Online: http://bna.birds.cornell.edu/bna/species/163

Bedard J. and G. Gauthier. 1986. Assessment of fecal output in geese. J. App. Ecol. 23:77-90.

Bedard J. and G. Gauthier. 1989. Comparative energy budgets of greater snow geese *Chen caerulescens atlantica* staging in two habitats in spring. Ardea 77(1):3-20.

Bell, J.F., G.W. Sciple, and A.A. Hubert. 1955. A macroenvironment concept of the epizoology of avian botulism. Journal of Wildlife Management 19:352-357.

Bellrose, F. C. 1980. Ducks, geese and swans of North America. Stackpole Books, Pub. Harrisburg, PA. 540 pp.

Brandvold, D.K., C.J. Popp, and J.A. Brierley. 1976. Waterfowl refuge effect on water quality: II. Chemical and physical parameters. J Water Pollut Control Fed. 48(4):680-687.

Buchanan, J.J., and W.P. Somers. 1969. Discharge measurements at gaging stations; techniques of water-resource investigations of the U.S. Geological Survey, Book 3, Chapter A8, 65 pp.

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography. 22:361-369.

Carlson, R.E. 1980. More complications in the chlorophyll-Secchi disk relationship. Limnology and Oceanography. 25:378-382.

Carlson, R.E. 1983. Discussion on "Using differences among Carlson's trophic state index values in regional water quality assessment", by Richard A. Osgood. Water Resources Bulletin. 19:307-309.

Carlson, R.E. 1992. Expanding the trophic state concept to identify non-nutrient limited lakes and reservoirs. pp. 59-71 [In] Proceedings of a National Conference on Enhancing the States' Lake Management Programs. Monitoring and Lake Impact Assessment. Chicago.

Carlson, R.E., and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.

Clark, R.G. and L.G. Sugden. 1990. The importance of agricultural foods in the annual diet of Mallard (*Anas platyrhynchos*) and Sandhill Crane (*Grus canadensis* L.). Pp. 317–331 *in* Granivorous birds in the agricultural landscape (J. Pinowski and J.D. Summers-Smith, eds.). Polish Sci. Publ., Warsaw, Poland.

Davis, S.E., E.E. Klaas, and K.J. Koehler. 1989. Diurnal time-activity budgets and habitat use of lesser snow geese *Anser caerulescens* in the middle Missouri River Valley during winter and spring. Wildfowl 40:45-54.

Drilling, N., R. Titman, and F. Mckinney. 2002. Mallard (Anas platyrhynchos), the Birds of North America Online (a. Poole, Ed.). Ithaca: Cornell Lab or Ornithology; Retrieved From the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/163

Eklund, M.W., and V.R. Dowell, Jr. 1987. Avian Botulism on international perspective. Charles C. Thomas Publisher, Springfield, Illinois. 405 pp.

Frederick, R.B., and E.E. Klaas. 1982. Resource use and behavior of migrating snow geese. J. Wildlife. Manage. 46(3):601-614.

Friend, M. 1987. Field guide to wildlife diseases. U.S. Fish and Wildlife Service Resource Publication No. 167. 225 pp.

Guy, H.P., and V.W. Norman. 1970. Field methods for measurement of fluvial sediment; techniques of water-resource investigations of the U.S. Geological Survey, Book 3, Chapter C2, 59 pp.

Gwiazda, R. 1996. Contribution of water birds to nutrient loading to the ecosystem of mesotrophic reservoir. Ekologia Polska 44(3-4):289-297.

Harkness, R. E., W.R. Berkas, S.W. Norbeck, and S.M. Robinson. 2000. Water resources data—North Dakota, Water Year 1999, Vol. 1 surface water. U.S. Geological Survey, Water Resources Division, Bismarck, ND. Water Data Report ND-99-1. 534 pp.

Harkness, R. E., W.R. Berkas, S.W. Norbeck, and S.M. Robinson. 2001. Water resources data—North Dakota, Water Year 2000, Vol. 1 surface water. U.S. Geological Survey, Water Resources Division, Bismarck, ND. Water Data Report ND-00-1. 477 pp.

Harkness, R. E., W.R. Berkas, S.W. Norbeck, and S.M. Robinson. 2002. Water resources data—North Dakota, Water Year 2001, Vol. 1 surface water. U.S. Geological Survey, Water Resources Division, Bismarck, ND. Water Data Report ND-01-1. 467 pp.

Hupp, J. W., R. G. White, J. S. Sedinger, and D. B. Robertson. 1996. Forage digestibility and intake by lesser snow geese: effects of dominance and resource heterogeneity. Oecologia 108:232-240.

Karasov, W.H. 1990. Digestion in birds: chemical and physiological determinants and ecological implications. Studies in Avian Biology 13:391-415.

Kendeigh, S.C., V.R. Dolnik, and V.M. Gavrilov. 1977. Avian energetics. Pages 127-204 in J. Pinowski and S.C. Kendeigh, eds. Granivorous birds in ecosystems. Cambridge University Press, London.

LaBaugh, J.W. 1989. Chemical characteristics of water in northern prairie wetlands. Pages 56-90 in Northern prairie wetlands, A. VanDerValk, editor. Iowa State University Press, Ames. 400 pp.

Malcolm, J.M. 1978. Study of wetland drainage in relation to Souris River water quality and quantity as it impacts J. Clark Salyer National Wildlife Refuge. U.S. Fish and Wildlife Service Unpublished Report. 24 pp.

Manny, B.A., R.G. Wetzel, and W.C. Johnon. 1975. Annual contribution of carbon, nitrogen and phosphorus by migrant Canada geese to hardwater lake. Ver. Internat. Verein. Limnol. 19:949-951.

Manny, B.A., W.C. Johnson, and Wetzel. 1994. Nutrient additions by waterfowl to lakes and reservoirs: predicting their effects on productivity and water quality. Hydrobiologia. 279/280:121-132.

Manseau, M. and G. Gauthier. 1993. Interactions between greater snow geese and their rearing habitat. Ecology 74(7): 2045-2055.

Marion, L., P. Clergeau, L. Brient, and G. Bertru. 1994. The importance of avian-contributed nitrogen (N) and phosphorus (P) to Lake Grand-Lieu, France. Hydrobiologia. 279/280:133-147.

Mowbray, T.B., F. Cooke, and B. Ganter. 2000. Snow Goose (*Chen caerulescens*). *In* The Birds of North America, No. 514 (A. Poole and F. Gill, eds.O. The Birds of North America, Inc., Philadelphia. PA.

Nagy, K. A., I. A. Girard, and T. K. Brown. 1999. Energetics of free-ranging mammals, reptiles, and birds. Annu. Rev. Nutr. 19:247-77.

Pettigrew, C.T., B.J. Hann, and L.G. Goldsborough. 1998. Waterfowl feces as a source of nutrients to prairie wetland: responses of microinvertebrates to experimental additions. Hydrobiologia 362:55-66.

Post, D.M., J.P. Taylor, J.F. Kitchell, M.H. Olson, D.E. Schindler, B.R. Herwig. 1998. The role of migratory waterfowl as nutrient vectors in a managed wetland. Conservation Biology. 12(4):910-920.

Rosen, M.N. 1971. Botulism. Pages 100-117 in Infectious and parasitic diseases of wild birds, J.W. Davis, editor. Iowa State University Press, Ames. 344 pp.

Scherer, N.M., H.L. Gibbons, K.B. Stoops, and M. Muller. 1995. Phosphorus loading of an urban lake by bird droppings. Lake and Reserv. Manage. 11(4):317-327.

Walker, W. W., 1998. Simplified procedures for eutrophication assessment and prediction: user manual. Instruction Report W-96-2. U.S. Army Corps of Engineers, Vicksburg, MS. 235 pp.

Wax, P. 1998. 1997 Souris River, McHenry County water quality assessment results. North Dakota Department of Health Division of Water Quality, Bismarck, ND. Unpub. Rep. 33 pp.

Wax, P. 2005. Lake water quality assessment for Lake Darling Renville and Ward Counties, North Dakota. North Dakota Department of Health Division of Water Quality, Bismarck, ND. Unpub. Rep. 27 pp.

Wilde, F.D., and D.B. Radtke. 1998. Field measurements, national field manual for the collection of water-quality data; U.S. Geological Survey techniques of water-resource investigations, Book 9, Chapter A6, 242 pp.

APPENDIX A

Laboratory analysis for major ion, nutrient, and physical constituents of inflows to J. Clark Salyer National Wildlife Refuge, North Dakota, 1999 and 2000.

Appendix A. Laboratory analysis for major ion, nutrient, and physical constituents of Souris River near Bantry.

Date	Flow cfs	NH3-4 mg/L	NO2+ NO3 mg/L	Nitrogen (Total Kjeldahl) mg/L	Total N mg/L	Total P mg/L	Diss. P mg/L	Total Dissolved Solids mg/L	Total Suspended Solids mg/l	SO4 mg/L	Na mg/L	Diss. Oxygen mg/l	Temp C
4/8/1999	2570	0.13	0.31	0.81	1.12	0.12	0.09	344.00	33.00	114	46.3	9.7	6.8
4/12/1999	2400	ND[a]	ND[b]	0.88	0.90	0.11	0.06	479.00	14.00	165	69.4	11.3	8.5
5/3/1999	2470	0.02	ND[b]	0.90	0.92	0.10	0.08	494.00	8.00	167	81.1	6	14.5
5/25/1999	2630	ND[a]	ND[b]	0.90	0.92	0.23	0.20	553.00	11.00	200	88	5.5	16.4
6/7/1999	2590	0.05	ND[b]	1.03	1.05	0.30	0.25	502.00	10.00	169	77.6	4.4	18.2
7/13/1999	763	ND[a]	ND[b]	1.18	1.20	0.29	0.22	633.00	218.00	193	114	5.6	23.5
8/3/1999	1120	ND[a]	ND[b]	1.09	1.11	0.28	0.21	630.00	49.00	204	104	10.2	22.7
8/24/1999	980	0.02	0.14	0.94	1.08	0.27	0.20	511.00	112.00	172	85	11.8	21.3
9/7/1999	700	0.02	0.14	0.92	1.06	0.28	0.19	623.00	746.00	192	120	–	17.8
9/28/1999	529	ND[a]	0.13	0.93	1.06	0.25	0.18	598.00	36.00	196	103	9.1	11.8
10/19/1999	492	0.02	0.06	0.88	0.94	0.19	0.13	608.00	31.00	207	99	11.1	6.2
4/19/2000	29	ND[a]	ND[b]	0.85	0.87	0.08	0.02	731.00	132.00	242	107	10.3	8.4
5/1/2000	25	ND[a]	ND[b]	1.14	1.16	0.13	0.07	785.00	41.00	261	123	12.5	17.8
6/6/2000	181	ND[a]	0.13	1.82	1.95	0.35	0.23	1400.00	226.00	547	317	9.8	18.8
6/26/2000	168	ND[a]	0.29	1.49	1.78	0.31	0.20	1170.00	174.00	489	222	6.6	20.9
7/25/2000	106	ND[a]	0.09	1.65	1.74	0.58	0.47	1280.00	64.00	492	293	7.1	23.9
8/22/2000	95	0.04	0.10	1.15	1.25	0.44	0.37	1030.00	46.00	374	216	4.6	19.0
9/19/2000	64	0.03	0.05	1.11	1.16	0.29	0.24	890.00	151.00	273	191	7.0	15.3
10/31/2000	51	0.09	0.07	0.99	1.06	0.20	0.14	950.00	38.00	297	193	11.9	10.2
11/14/2000	140	0.06	0.17	1.03	1.20	0.16	0.12	1060.00	17.00	446	183	13.6	0.0

[a] ND= below detection limit (<.01 mg/L for NH_3)
[b] ND= below detection limit (<.02 mg/L for NO_2+NO_3)

Appendix A . Laboratory analysis for major ion, nutrient, and physical constituents of Souris River near Bantry (continued)

Date	Fecal Coliforms #/100 ml	Chlorophyll A ug/L	pH	Conductivity umhos/cm
4/8/1999	6	5	7.38	559
4/12/1999	1	8	8.19	748
5/3/1999	48	3	7.1	743
5/25/1999	14	3	7.52	842
6/7/1999	42	3	7.35	798
7/13/1999	29	19	7.69	977
8/3/1999	24	3	7.87	977
8/24/1999	39	3	8.03	829
9/7/1999	90	31	8.26	969
9/28/1999	21	11	8.2	954
10/19/1999	14	16	8.25	949
4/19/2000	6	3	8.05	1110
5/1/2000	5	3	8.28	1210
6/6/2000	25	36	8	2080
6/26/2000	51	29	8.24	1680
7/25/2000	230	30	8.33	1870
8/22/2000	73	16	8.39	1510
9/19/2000	177	3	8.37	1340
10/31/2000	27	25	8.16	1430
11/14/2000	60	3	8.15	1600

Appendix A . Laboratory analysis for major ion, nutrient, and physical constituents of Willow Creek near Willow City.

Date	**Flow cfs**	**NH3-4 mg/L**	**NO2+ NO3 mg/L**	**Nitrogn (Total Kjldahl) mg/L**	**Total N mg/L**	**Total P mg/L**	**Dissolved P mg/L**	**Total Dissolved Solids mg/L**	**Total Suspended Solids mg/l**	**SO4 mg/L**	**Na mg/L**	**Dissolved Oxygen mg/L**	**Temp C**
4/8/1999	1600	0.09	0.88	1.06	1.94	0.27	0.27	284.00	80.00	97.8	40.1	8.5	4.4
4/12/1999	2340	ND[a]	0.27	0.95	1.22	0.21	0.21	308.00	13.00	110	45.9	8.9	8.6
5/3/1999	520	ND[a]	ND[b]	1.37	1.39	0.10	0.04	600.00	11.00	214	70.4	7.2	14.2
5/25/1999	1460	ND[a]	ND[b]	1.25	1.27	0.08	0.08	655.00	3.00	248	88.5	7.5	17.1
6/7/1999	1190	ND[a]	ND[b]	1.54	1.56	0.15	0.12	555.00	4.00	188	65.4	4.0	20.0
7/13/1999	178	0.07	ND[b]	2.06	2.08	0.26	0.26	609.00	144.00	153	68.7	6.1	25.0
8/24/1999	85	ND[a]	0.23	2.38	2.61	0.30	0.25	936.00	21.00	332	151	14.1	21.3
9/7/1999	43	0.11	0.24	1.95	2.19	0.27	0.23	858.00	399.00	250	134	–	19.1
9/28/1999	16	0.02	ND[b]	1.85	1.87	0.21	0.15	1410.00	21.00	520	241	14.6	10.7
10/19/1999	9	ND[a]	ND[b]	1.71	1.73	0.05	0.04	1020.00	75.00	343	150	13.8	4.8
4/19/2000	102	ND[a]	ND[b]	1.42	1.44	0.07	0.02	949.00	72.00	399	216	9.8	8.7
5/1/2000	66	ND[a]	ND[b]	1.64	1.66	0.12	0.07	928.00	53.00	365	207	11.1	17.4
6/6/2000	67	ND[a]	ND[b]	1.74	1.76	0.16	0.08	950.00	56.00	403	235	9.5	18.9
6/26/2000	77	ND[a]	ND[b]	2.26	2.28	0.20	0.16	1450.00	89.00	696	199	6.0	21.2
7/25/2000	125	ND[a]	0.03	2.07	2.10	0.33	0.28	1040.00	33.00	398	140	8.4	24.3
8/22/2000	17	0.03	ND[b]	2.00	2.02	0.25	0.19	1150.00	41.00	472	127	5.2	18.5
9/19/2000	3	0.06	ND[b]	2.02	2.04	0.19	0.12	1170.00	96.00	476	131	6.2	14.3
10/31/2000	16	0.17	0.10	2.10	2.20	0.15	0.08	1280.00	42.00	520	248	12.1	9.7
11/14/2000	78	0.14	0.26	1.82	2.08	0.20	0.15	1280.00	28.00	616	182	10.1	0.0

[a] ND= below detection limit (<.01 mg/L for NH_3)

[b] ND= below detection limit (<.02 mg/L for NO_2+NO_3)

Appendix A . Laboratory analysis for major ion, nutrient, and physical constituents of Willow Creek near Willow City.(continued).

Date	Fecal Coliforms #/100 ml	Chlorophyll A ug/L	pH	Conductivity umhos/cm
4/8/1999	4	3	6.78	463
4/12/1999	2	3	7.12	504
5/3/1999	46	3	7.6	911
5/25/1999	8	3	7.99	989
6/7/1999	39	3	7.54	881
7/13/1999	36	3	7.9	954
8/24/1999	80	3	8.22	1420
9/7/1999	420	3	8.36	1310
9/28/1999	80	52	8.65	2060
10/19/1999	41	38	8.59	1520
4/19/2000	5	3	8.36	1360
5/1/2000	55	12	8.52	1370
6/6/2000	100	9	8.25	1430
6/26/2000	110	3	8.53	1980
7/25/2000	136	17	8.3	1560
8/22/2000	300	44	8.41	1610
9/19/2000	960	21	8.49	1660
10/31/2000	82	21	8.4	1780
11/14/2000	56	3	7.92	1880

Appendix A . Laboratory analysis for major ion, nutrient, and physical constituents of Stone Creek near Kramer.

Date	Flow cfs	NH3-4 mg/L	NO2+ NO3 mg/L	Nitrogen (Total Kjeldahl) mg/L	Total N mg/L	Total P mg/L	Dissolved P mg/L	Total Dissolved Solids mg/L	Total Suspended Solids mg/l	SO4 mg/L	Na mg/L	DO mg/L	Temp C
4/6/1999	290	0.31	3.00	0.89	3.89	0.35	0.35	188.00	47.00	48.6	16	9.9	1.3
4/9/1999	771	0.07	1.91	0.35	2.26	0.36	0.35	172.00	82.00	40.2	14.5	8.8	8.9
4/13/1999	175	0.04	0.65	0.80	1.45	0.33	0.32	216.00	67.00	60.7	18	9.0	10.1
5/4/1999	6	ND[a]	ND[b]	1.30	1.32	0.48	0.43	630.00	19.00	247	76	5.8	14.8
5/11/1999	152	ND[a]	ND[b]	1.12	1.14	0.11	0.07	548.00	149.00	272	64.6	11.8	6.8
5/26/1999	46	ND[a]	ND[b]	1.35	1.37	0.21	0.19	912.00	14.00	453	135	6.3	17.1
6/8/1999	139	0.11	0.06	1.64	1.70	0.39	0.32	691.00	28.00	311	93	5.9	21.0
7/14/1999	2	ND[a]	ND[b]	1.95	1.97	0.56	0.57	644.00	7.00	207	84.9	6.9	24.0
8/24/1999	3	ND[a]	ND[b]	1.50	1.52	0.29	0.26	617.00	-	198	103	8.6	21.2
9/29/1999	0.3	0.02	ND[b]	1.97	1.99	0.46	0.44	1120.00	30.00	491	166	11.0	8.5
4/18/2000	5	ND[a]	ND[b]	1.82	1.84	0.09	0.04	2130.00	8.00	1210	336	9.4	7.3
5/3/2000	1	ND[a]	ND[b]	2.29	2.31	0.30	0.20	2280.00	25.00	1270	363	8.0	15.7
5/17/2000	24	ND[a]	0.04	2.00	2.04	0.14	0.11	2530.00	14.00	1450	418	21.6	15.7
5/31/2000	1	ND[a]	ND[b]	2.31	2.33	0.28	0.25	2930.00	7.00	1740	496	8.7	16.0
6/7/2000	0.5	ND[a]	ND[b]	2.45	2.47	0.35	0.29	2850.00	10.00	1690	485	8.3	18.7
6/27/2000	2	0.10	0.04	2.49	2.53	0.46	0.41	1770.00	310.00	993	292	12.2	20.4

[a] ND= below detection limit (<.01 mg/L for NH_3)
[b] ND= below detection limit (<.02 mg/L for NO_2+NO_3)

Appendix A . Laboratory analysis for major ion, nutrient, and physical constituents of Stone Creek near Kramer (continued)

Date	Fecal Coliforms #/100 ml	Chorophyll A ug/L	pH	Conductivity umhos/cm
4/6/1999	112	3	6.74	314
4/9/1999	121	3	7.07	287
4/13/1999	36	9	7.17	365
5/4/1999	86	5	7.32	936
5/11/1999	1320	3	7.56	850
5/26/1999	73	3	7.7	1320
6/8/1999	257	3	7.61	1050
7/14/1999	26	3	8.45	970
8/24/1999	14	3	8.15	1000
9/29/1999	84	45	8.59	1610
4/18/2000	–	3	8.17	2660
5/3/2000	67	16	8.31	2850
5/17/2000	116	6	8.35	3110
5/31/2000	413	3	8.22	3500
6/7/2000	–	3	8.26	3650
6/27/2000	>38	3	8.45	2260

Appendix A . Laboratory analysis for major ion, nutrient, and physical constituents of Deep River near Upham.

Date	Flow cfs	NH3-4 mg/L	NO2+ NO3 mg/L	Nitrogen (Total Kjeldahl) mg/L	Total N mg/L	Total P mg/L	Dissolved P mg/L	Total Dissolved Solids mg/L	Total Suspended Solids mg/L	SO4 mg/L	Na mg/L	DO mg/L	Temp C
3/31/1999	1300	0.28	0.54	1.08	1.62	0.24	0.26	143.00	92.00	33	8.3	10.50	1.5
4/12/1999	910	0.02	ND[b]	0.95	0.97	0.17	0.11	247.00	12.00	56.7	15.1	9.40	10.8
5/3/1999	64	ND[a]	ND[b]	1.22	1.24	0.26	0.21	420.00	41.00	95.7	29	9.00	16.0
5/25/1999	579	ND[a]	ND[b]	1.32	1.34	0.17	0.15	556.00	4.00	156	43.6	7.50	17.9
6/7/1999	153	0.03	0.06	1.48	1.54	0.28	0.23	538.00	16.00	156	40.6	6.40	21.0
7/13/1999	11	0.02	ND[b]	1.88	1.90	0.29	0.26	631.00	18.00	137	55.1	7.00	26.0
8/3/1999	26	ND[a]	ND[b]	2.17	2.19	0.26	0.25	648.00	4.00	134	61.7	10.10	22.9
8/24/1999	17	ND[a]	ND[b]	1.97	1.99	0.21	0.18	581.00	16.00	116	57.7	19.00	22.5
9/8/1999	11	0.07	0.06	1.82	1.88	0.15	0.12	613.00	4.00	129	60.6	–	15.8
9/28/1999	3	0.02	ND[b]	1.78	1.80	0.09	0.08	595.00	10.00	143	54.5	11.80	11.4
10/19/1999	-	ND[a]	ND[b]	1.71	1.73	0.04	0.03	648.00	10.00	173	57.3	12.80	5.8
4/19/2000	4	ND[a]	ND[b]	1.92	1.94	0.04	0.02	897.00	9.00	367	74.3	11.00	9.4
5/3/2000	3	ND[a]	ND[b]	2.23	2.25	0.11	0.01	946.00	8.00	395	76.2	9.60	18.7
6/6/2000	5	ND[a]	ND[b]	1.89	1.91	0.12	0.08	906.00	6.00	280	94.5	8.80	19.7
6/26/2000	17	ND[a]	0.05	2.29	2.34	0.23	0.19	854.00	13.00	283	83	5.20	21.0
7/25/2000	47	0.06	0.12	1.76	1.88	0.61	0.54	567.00	22.00	95.1	65	6.80	24.0
8/22/2000	7	0.08	0.08	1.80	1.88	0.29	0.26	647.00	-	196	61.8	3.40	20.0
9/19/2000	1	0.04	ND[b]	1.81	1.83	0.23	0.14	666.00	21.00	229	60.1	8.60	15.4
10/31/2000	0	0.15	0.05	1.71	1.76	0.10	0.05	747.00	43.00	267	67	12.00	10.0
11/15/2000	0	0.06	0.57	1.86	2.43	0.06	0.03	802.00	-	323	63.9	13.50	0.9

[a] ND= below detection limit (<.01 mg/L for NH_3)
[b] ND= below detection limit (<.02 mg/L for NO_2+NO_3)

Appendix A . Laboratory analysis for major ion, nutrient, and physical constituents of Deep River near Upham (continued)

Date	**Fecal Coliforms #/100 ml**	**Chlorophyll A ug/L**	**pH**	**Conductivity umhos/cm**
3/31/1999	–	3	6.98	273
4/12/1999	7	7	7.36	424
5/3/1999	250	5	7.6	690
5/25/1999	26	3	7.96	879
6/7/1999	1150	3	7.75	867
7/13/1999	250	3	8.18	1010
8/3/1999	56	3	8.09	1060
8/24/1999	80	3	8.46	999
9/8/1999	60	3	8.46	1030
9/28/1999	14	11	8.63	984
10/19/1999	22	17	8.68	1040
4/19/2000	1	37	8.39	1320
5/3/2000	11	6	8.37	1410
6/6/2000	160	3	8.31	1450
6/26/2000	73	13	8.37	1310
7/25/2000	100	3	8.05	993
8/22/2000	92	7	8.44	1010
9/19/2000	90	10	8.61	1050
10/31/2000	18	51	8.38	1120
11/15/2000	8	24	8.09	1270

Appendix A . Laboratory analysis for major ion, nutrient, and physical constituents of Cut Bank Creek near Upham.

Date	Flow cfs	NH3-4 mg/L	NO2+ NO3 mg/L	Nitrogen (Total Kjeldahl) mg/L	Total N mg/L	Total P mg/L	Dissolved P mg/L	Total Dissolved Solids mg/L	Total Suspended Solids mg/L	SO4 mg/L	Na mg/L	DO mg/L	Temp C
3/31/1999	47	0.22	0.21	0.98	1.19	0.34	0.34	350.00	7.00	102	39.4	8.00	0.50
4/9/1999	484	ND[a]	0.08	0.71	0.79	0.15	0.12	263.00	9.00	88.7	30.9	9.30	7.40
4/12/1999	303	ND[a]	ND[b]	1.05	1.07	0.17	0.08	291.00	5.00	97.6	32.3	8.60	9.90
5/3/1999	67	ND[a]	ND[b]	1.25	1.27	0.16	0.11	555.00	3.00	198	71.9	6.20	15.20
5/11/1999	186	0.10	0.58	1.15	1.73	0.30	0.20	524.00	167.00	168	74.5	10.70	6.70
5/25/1999	223	ND[a]	ND[b]	1.21	1.23	0.08	0.07	609.00	11.00	217	82.7	8.30	19.80
6/7/1999	154	ND[a]	ND[b]	1.36	1.38	0.13	0.10	665.00	54.00	257	84.5	4.40	21.20
7/13/1999	82	ND[a]	ND[b]	1.74	1.76	0.16	0.14	721.00	2.00	241	98.3	1.60	25.00
8/24/1999	25	ND[a]	0.05	1.74	1.79	0.24	0.23	730.00	7.00	236	101	10.40	22.00
9/28/1999	15	ND[a]	ND[b]	1.40	1.42	0.16	0.14	765.00	2.00	241	104	10.60	10.90
4/20/2000	8	ND[a]	ND[b]	1.46	1.48	0.13	0.11	860.00	4.00	285	111	8.20	6.50
5/3/2000	1	ND[a]	ND[b]	1.99	2.01	0.34	0.28	965.00	29.00	316	132	9.70	17.80
5/17/2000	13	ND[a]	ND[b]	1.61	1.63	0.25	0.22	958.00	3.00	332	124	9.80	12.60
5/31/2000	5	ND[a]	ND[b]	1.91	1.93	0.41	0.38	987.00	7.00	340	137	7.90	14.00
6/6/2000	3	ND[a]	ND[b]	1.85	1.87	0.32	0.28	954.00	2.00	327	134	10.40	21.90
6/26/2000	6	ND[a]	ND[b]	2.06	2.08	0.35	0.33	860.00	13.00	303	120	4.40	21.60

[a] ND= below detection limit (<.01 mg/L for NH_3)
[b] ND= below detection limit (<.02 mg/L for NO_2+NO_3)

Appendix A . Laboratory analysis for major ion, nutrient, and physical constituents of Cut Bank Creek near Upham (continued)

Date	Fecal Coliforms #/100 ml	Chlorophyll A ug/L	pH	Conductivity Umhos/cm
3/31/1999	–	3.00	7.43	593.00
4/9/1999	0	3.00	7.07	444.00
4/12/1999	5	5.00	7.25	486.00
5/3/1999	30	3.00	7.26	862.00
5/11/1999	9	3.00	7.68	776.00
5/25/1999	4	3.00	7.93	934.00
6/7/1999	14	3.00	7.48	1020.00
7/13/1999	11	3.00	7.37	1120.00
8/24/1999	18	3.00	7.99	1170.00
9/28/1999	228	7.00	8.26	1200.00
4/20/2000	0	3.00	8.18	1310.00
5/3/2000	21	7.00	8.46	1440.00
5/17/2000	20	3.00	8.26	1440.00
5/31/2000	34	3.00	8.47	1460.00
6/6/2000	16	3.00	8.54	1440.00
6/26/2000	18	3.00	8.65	1260.00

Appendix A . Laboratory analysis for major ion, nutrient, and physical constituents of Boundary Creek near Landa.

Date	Flow cfs	NH3-4 mg/L	NO2+ NO3 mg/L	Nitrogen (Total Kjeldal) mg/L	Total N mg/L	Total P mg/L	Dissolved P mg/L	Total Dissolved Solids mg/L	Total Suspended Solids mg/L	SO4 mg/L	Na mg/L	DO mg/L	Temp C
4/7/1999	804	0.19	2.24	0.98	3.22	0.39	0.35	177.00	44.00	41.2	16.1	10.0	4.5
4/10/1999	723	0.02	1.42	0.48	1.90	0.31	0.25	159.00	72.00	32.1	12.6	9.5	6.8
4/13/1999	347	0.06	0.55	0.86	1.41	0.28	0.24	221.00	46.00	60.7	22.4	9.2	10.7
5/4/1999	12	ND[a]	ND[b]	1.47	1.49	0.23	0.19	950.00	8.00	394	140	9.3	16.3
5/12/1999	308	ND[a]	0.22	1.15	1.37	0.27	0.20	559.00	11.00	240	84.7	11.0	7.5
5/26/1999	175	ND[a]	ND[b]	1.25	1.27	0.28	0.32	657.00	10.00	286	102	5.8	19.6
6/8/1999	592	0.06	0.10	1.33	1.43	0.27	0.26	505.00	38.00	214	83	5.2	20.7
7/14/1999	5	ND[a]	ND[b]	1.69	1.71	0.29	0.30	1020.00	7.00	403	152	14.8	25.8
8/25/1999	3	ND[a]	0.10	2.18	2.28	0.54	0.49	1270.00	27.00	576	200	18.3	22.5
9/29/1999	1	ND[a]	ND[b]	2.13	2.15	0.23	0.19	1640.00	24.00	794	295	12.1	9.1
4/17/2000	10	ND[a]	ND[b]	1.64	1.66	0.09	0.04	1780.00	9.00	900	325	–	6.6
5/2/2000	5	ND[a]	ND[b]	1.89	1.91	0.23	0.18	1900.00	23.00	977	324	10.1	14.5
5/17/2000	23	ND[a]	ND[b]	1.82	1.84	0.14	0.11	2240.00	46.00	1200	403	21.0	16.6
5/31/2000	7	ND[a]	ND[b]	1.82	1.84	0.29	0.26	1600.00	11.00	778	271	9.5	16.5
6/7/2000	4	ND[a]	ND[b]	1.83	1.85	0.27	0.22	1540.00	8.00	747	259	7.0	22.9
6/27/200	5	ND[a]	ND[b]	2.44	2.46	0.32	0.28	1910.00	20.00	989	347	10.5	18.7

0													
7/26/2000	-	ND[a]	ND[b]	1.72	1.74	0.47	0.45	977.00	--	381	184	-	-
9/20/2000	-	ND[a]	ND[b]	1.67	1.69	0.34	0.28	981.00	--	358	187	-	-
11/1/2000	-	0.12	0.03	1.96	1.99	0.13	0.05	1050.00	--	362	230	-	-

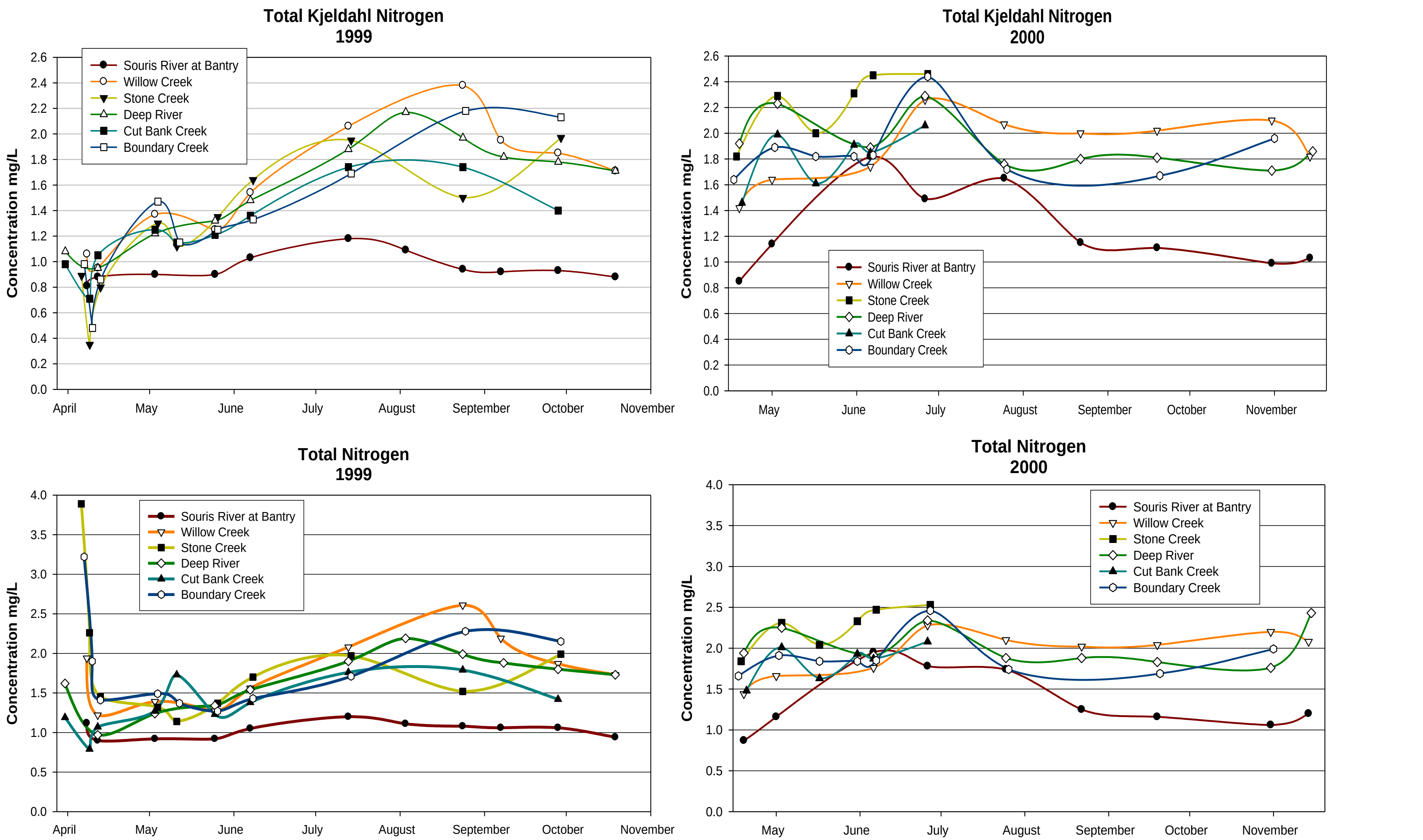
[a] ND= below detection limit (<.01 mg/L for NH_3)
[b] ND= below detection limit (<.02 mg/L for NO_2+NO_3)

Appendix A . Laboratory analysis for major ion, nutrient, and physical constituents of Boundary Creek near Landa (continued)

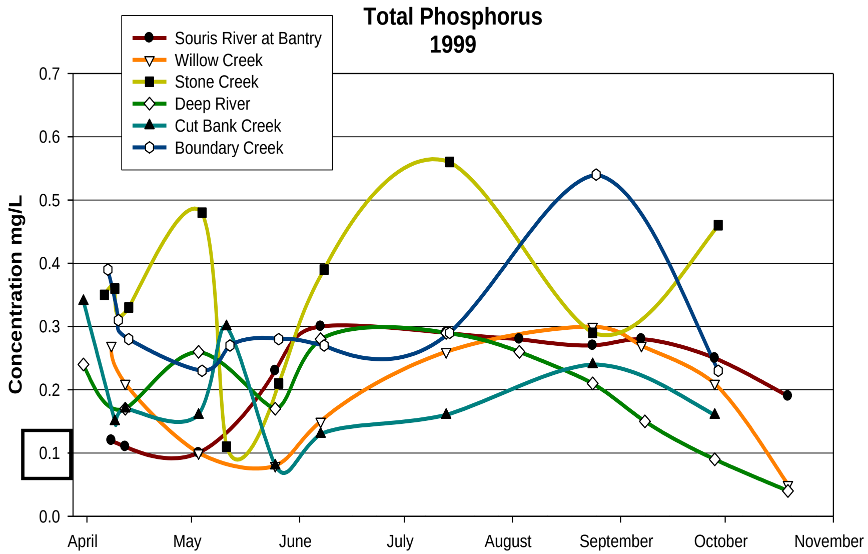
Date	Fecal Coliforms #/100 ml	Chlorophyll A ug/L	pH	Conductivity umhos/cm
4/7/1999	5	3	6.87	302
4/10/1999	10	3	6.84	268
4/13/1999	64	3	7.12	363
5/4/1999	940	3	7.89	1370
5/12/1999	78	3	7.56	845
5/26/1999	93	3	7.78	988
6/8/1999	406	3	7.22	796
7/14/1999	71	3	8.74	1430
8/25/1999	120	3	8.51	1800
9/29/1999	252	22	8.67	2230
4/17/2000	7	27	8.46	2340
5/2/2000	31	15	8.49	2490
5/17/2000	1240	13	8.49	2830
5/31/2000	100	3	8.36	2080
6/7/2000	520	5	8.4	2120
6/27/2000	200	3	8.5	2450
7/26/2000	-	3	8.76	1460
9/20/2000	-	35	8.96	1510
11/1/2000	-	92	8.59	1540

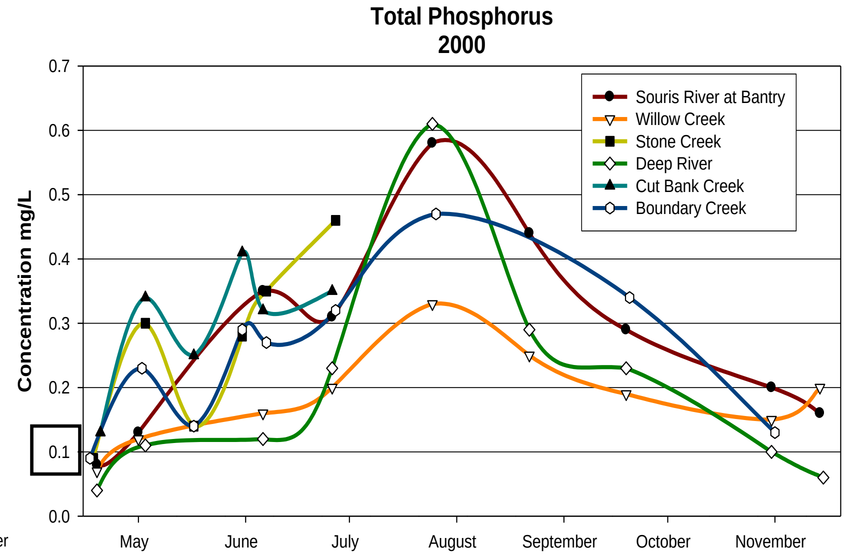
APPENDIX B

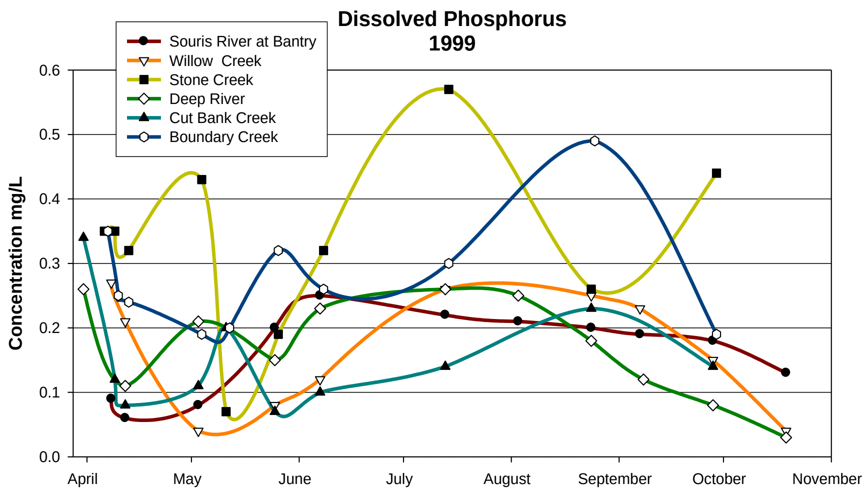
1999 and 2000 yearly comparisons of water quality parameter seasonal trends in inflows to J. Clark Salyer NWR, North Dakota.

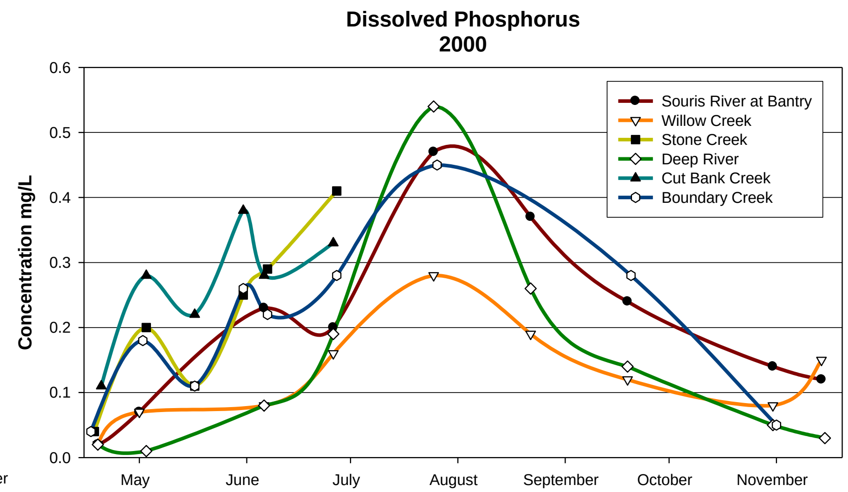


Appendix B. 1999 and 2000 yearly comparisons of water quality parameter seasonal trends in inflows to J. Clark Salyer NWR, North Dakota.

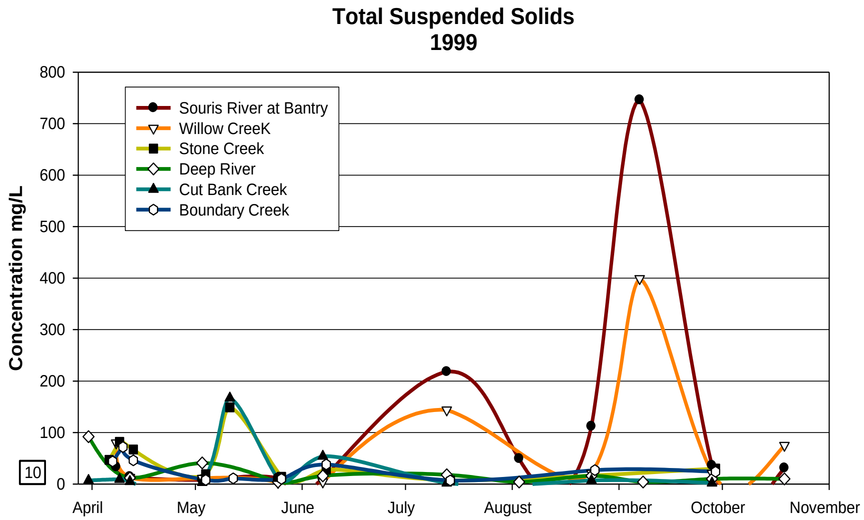


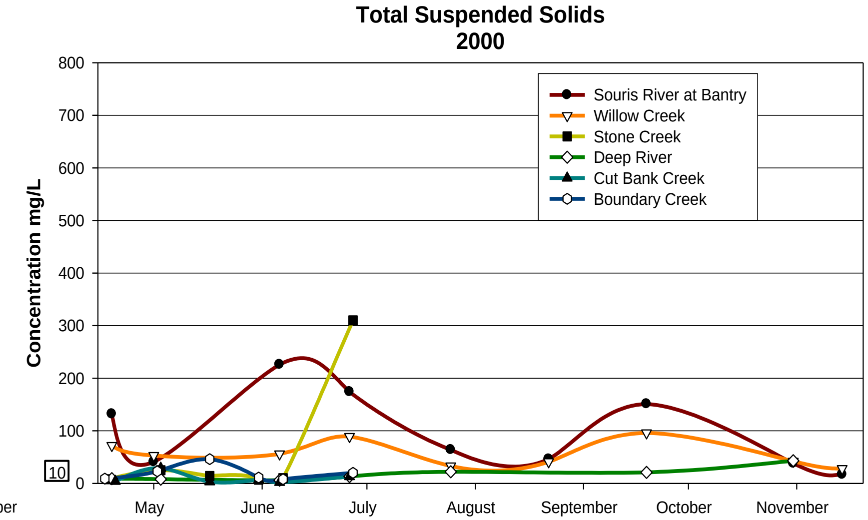


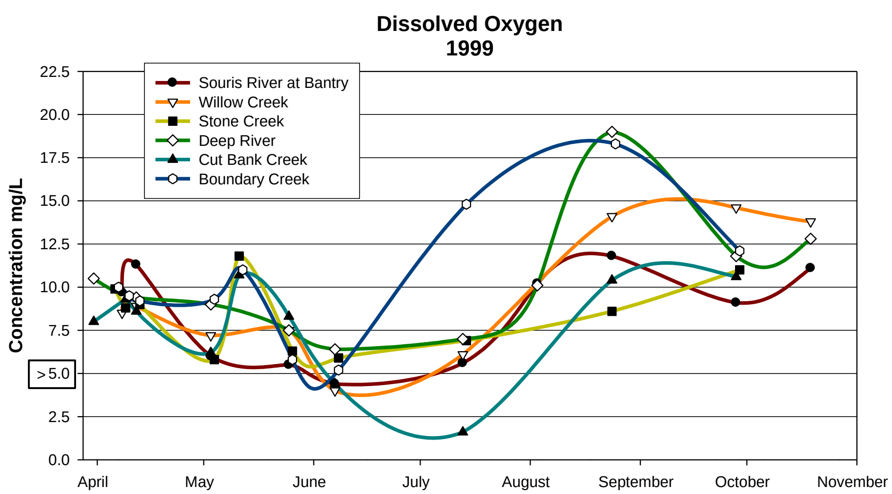


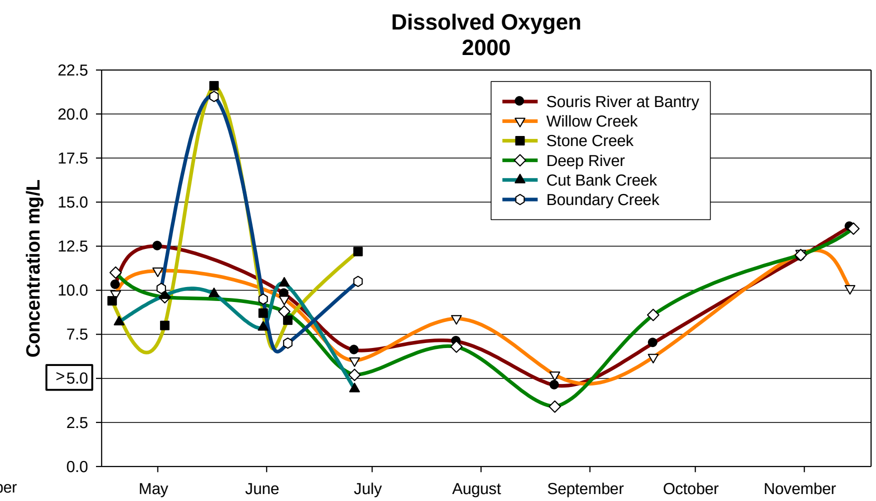


App. B Cont.. ☐ = Transboundary Water Quality Objective.



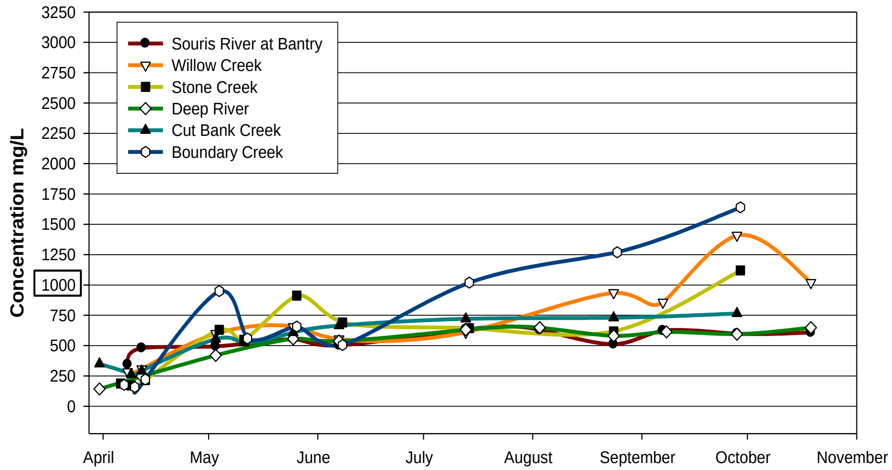




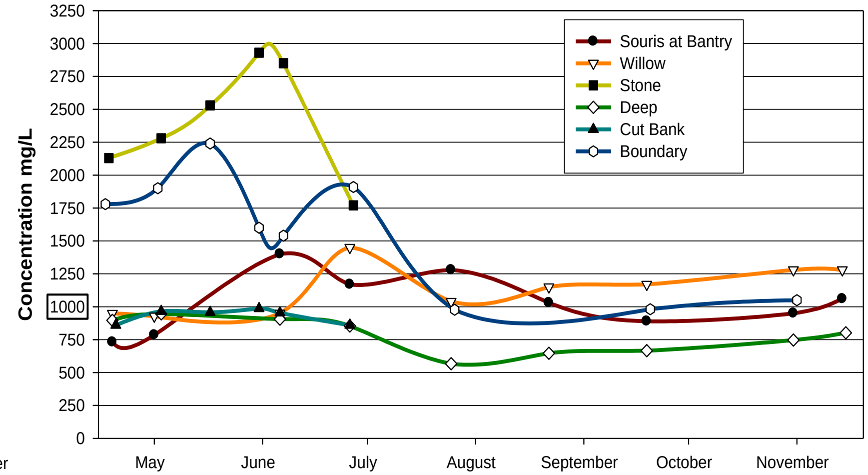


App. B Cont.. ☐ = Transboundary Water Quality Objective.

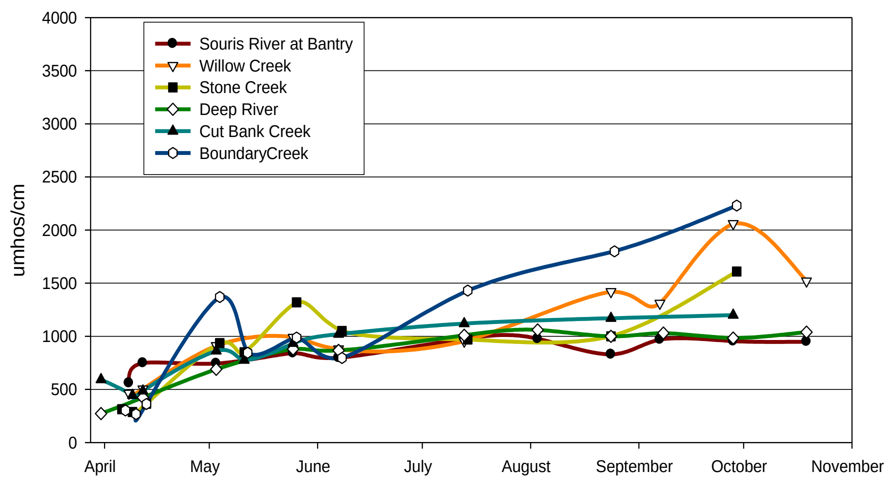
Total Dissolved Solids
1999



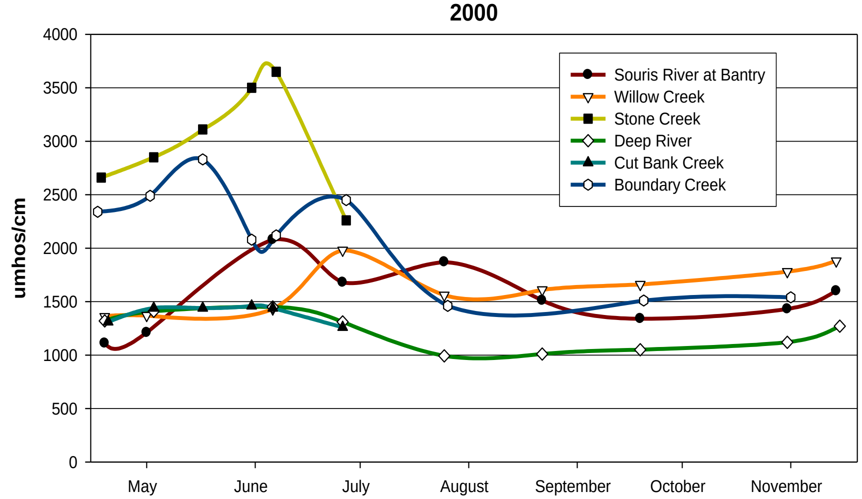
Total Dissolved Solids
2000



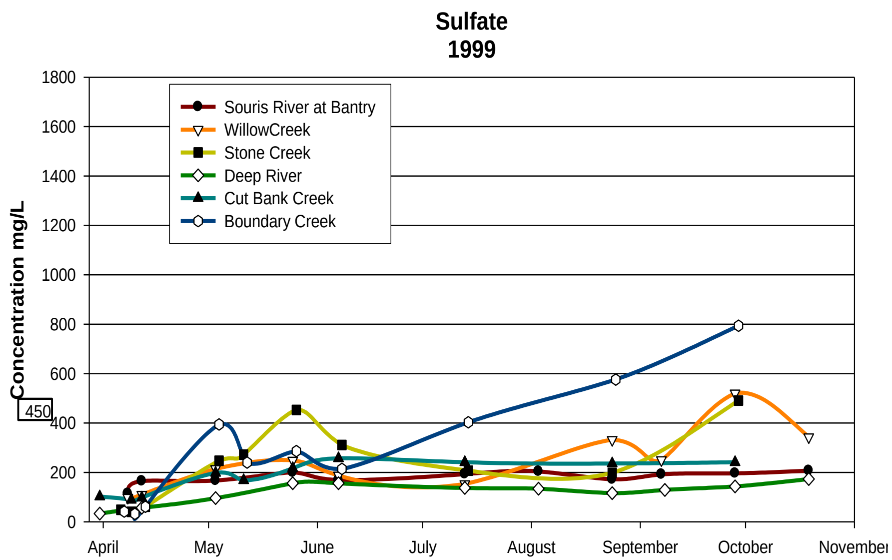
Conductivity
1999

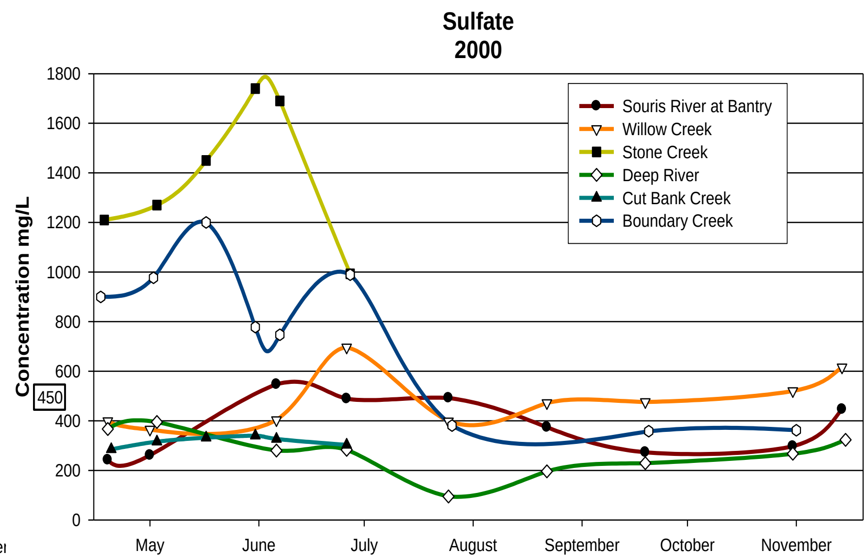


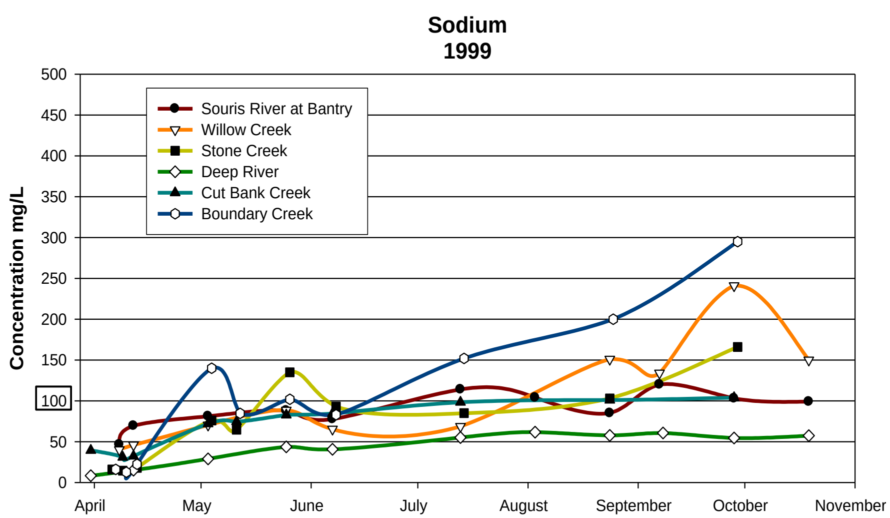
Conductivity
2000

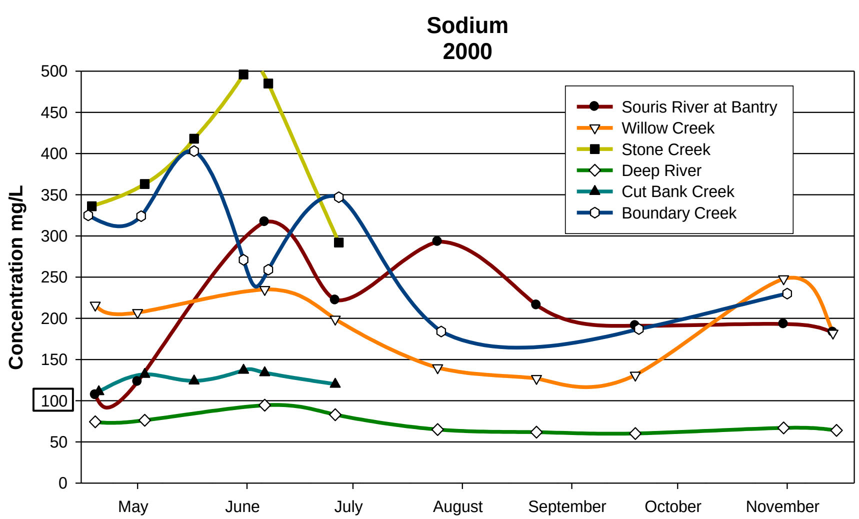


App. B Cont. ☐ = Transboundary Water Quality Objective.

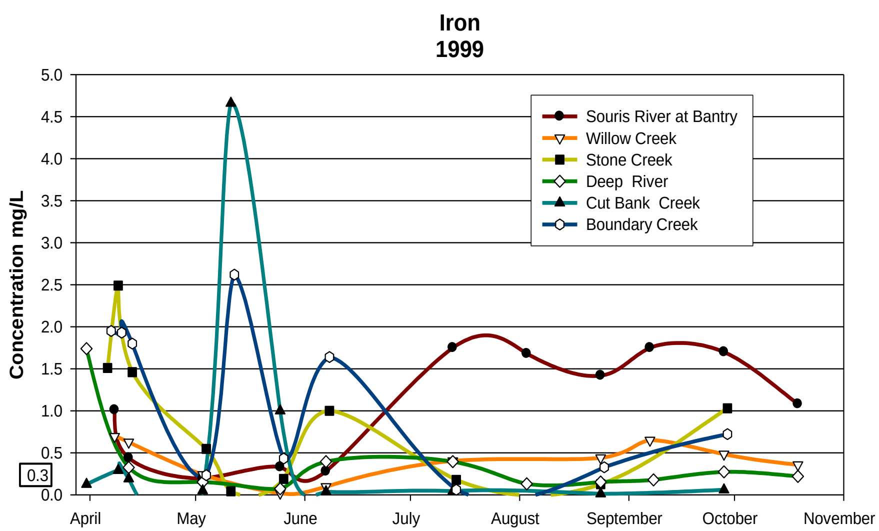


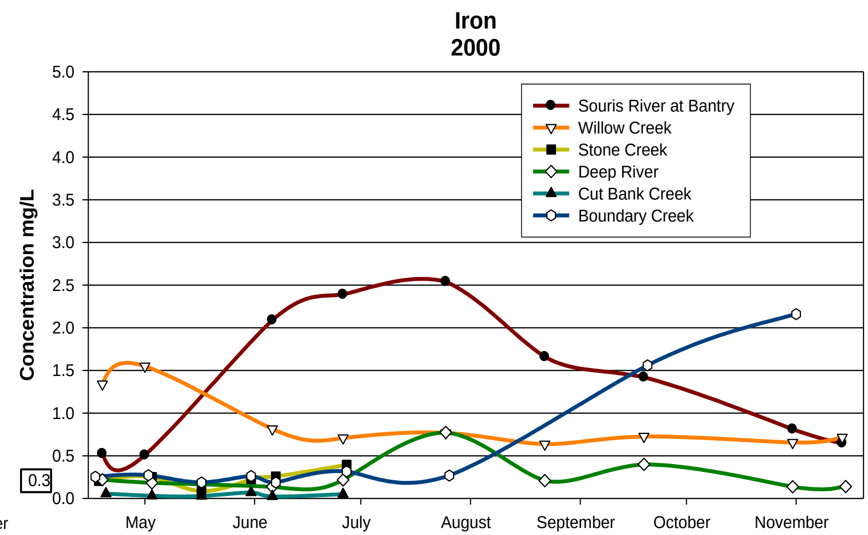


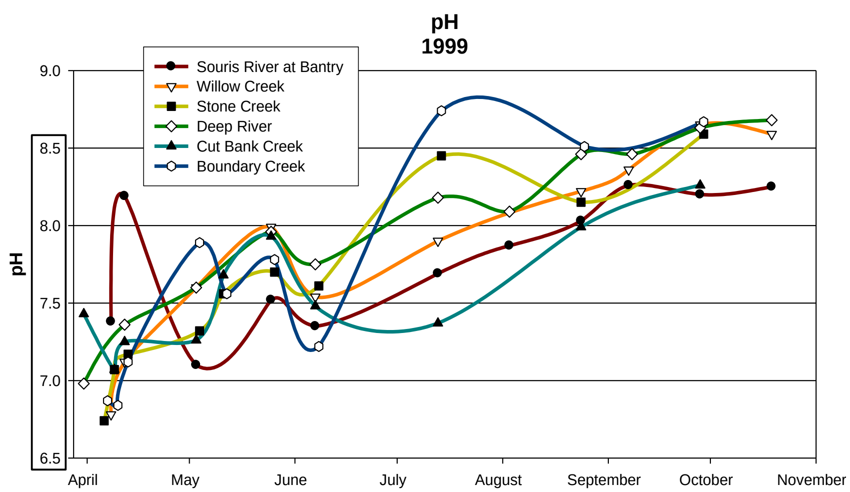


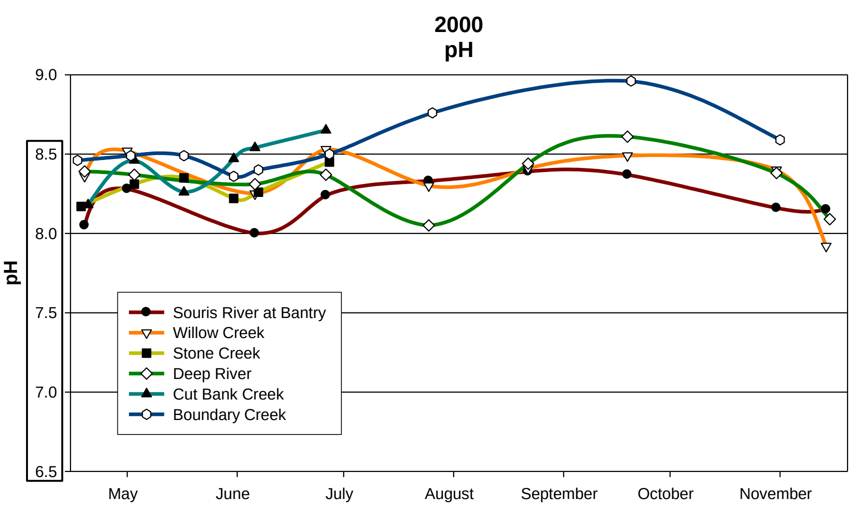


App. B Cont.. ☐ = Transboundary Water Quality Objective.

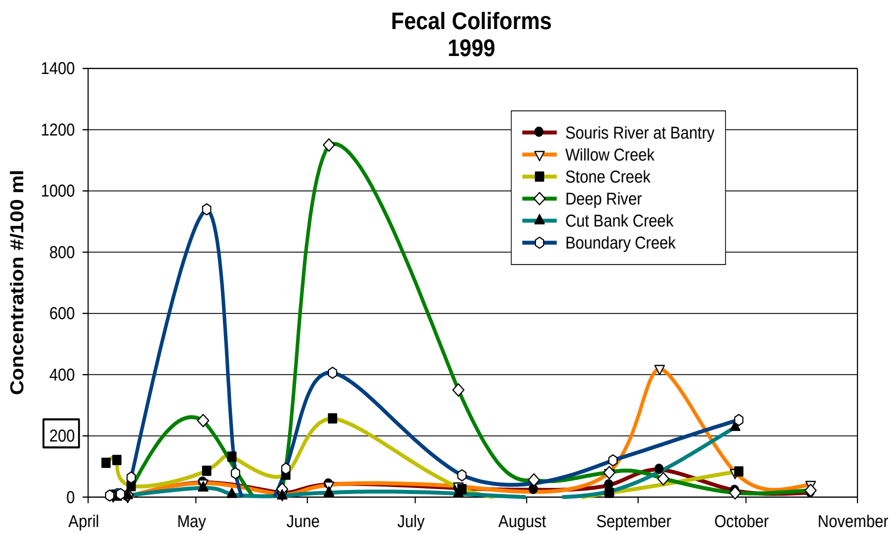


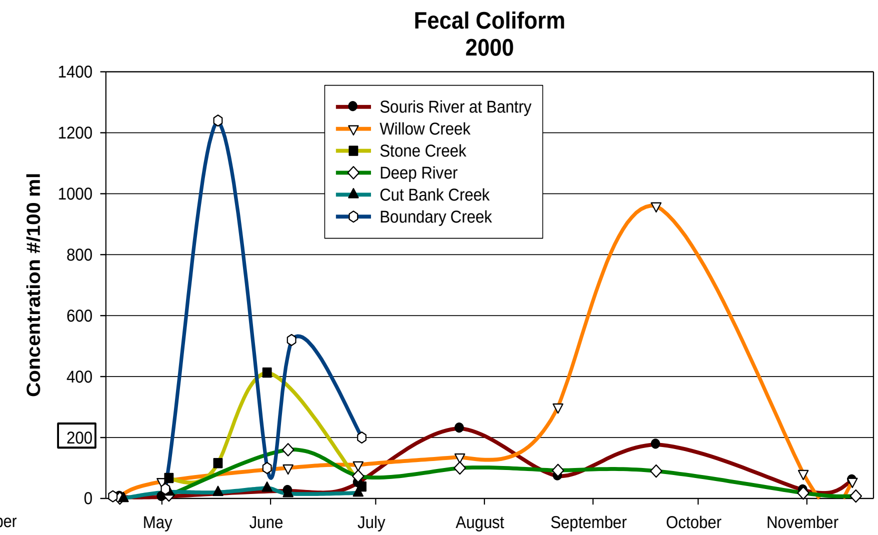


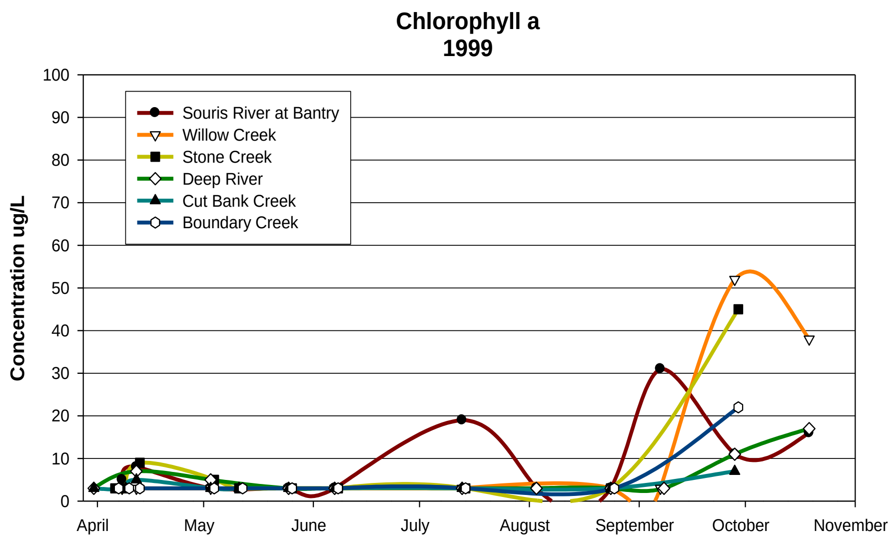


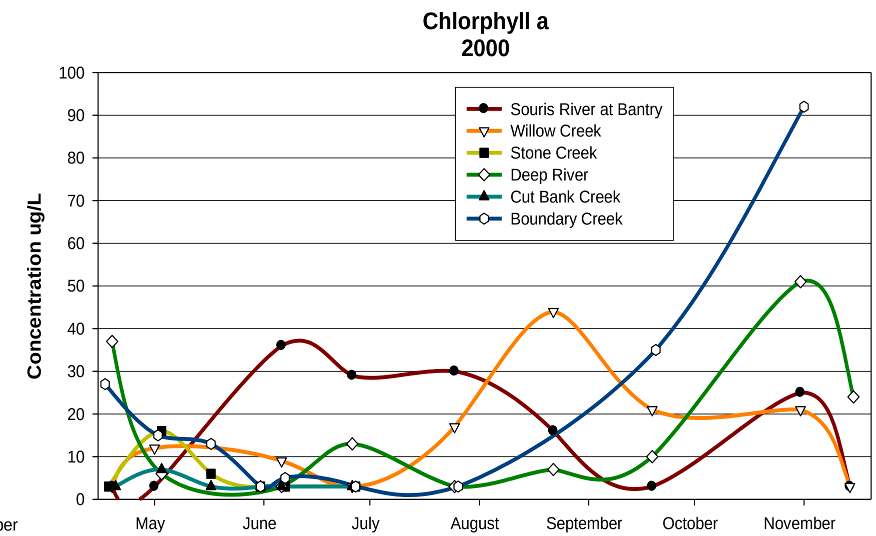


App. B Cont… = Transboundary Water Quality Objective.









App. B Cont.. $\boxed{}$ = Transboundary Water Quality Objective.